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BRITISH NUCLEAR ENERGY CONFERENCE

The British Nuclear Energy Conference held its Inaugural Meeting in the Institution of Civil Engineers on November 30th, and a report of its proceedings appears elsewhere in this issue. The conference has been set up jointly by the Institutions of Civil, Mechanical, Electrical and Chemical Engineers and the Institute of Physics to provide a common ground between scientists and engineers where developments in the technology of nuclear energy can be discussed. The papers that were read at this first meeting demonstrate how wide is the field of nuclear energy, and yet how interdependent are its features. For example, any plans that are made to meet the Central Electricity Authority's estimate of the amount of power that nuclear energy will have to provide must also take into account the health and safety problems that were reviewed by Dr. McLean and Dr. Marley. The present stage of nuclear energy development, even apart from the novelty of the fission process itself, offers an unusual setting in which the engineer must work. Not only does nuclear engineering extend across all existing branches of engineering into science, but its technology is being established at a time when research and development are constantly introducing new ideas and offering new goals. Even inside the bounds of conventional engineering it is impossible to optimise a design within any one field alone. The method of charging a reactor, which is essentially a mechanical engineering problem, might well have a profound effect on the civil engineer's design of the reactor shield. Then, too, safety cannot be assured by the application of safety controls to a completed design. A proper balance needs to be struck between the reliability of, say, the coolant circuits and the reliability of the instrumentation that may be installed to operate when such a circuit fails. In fact, even with the comparatively simple reactors being designed to-day, it will be some years before design can be broken down into purely specialist compartments. Meantime, it is essential that the nuclear engineer has opportunity to familiarise himself with major developments in the whole field of nuclear energy, and membership of the British Nuclear Energy Conference should enable him to do this.

Although the United Kingdom Atomic Energy Authority has a statutory duty to undertake certain aspects of technical training, the B.N.E.C. in time may well have an important part to play. The setting-up of the conference will undoubtedly stimulate interest in nuclear energy among young students and graduates of the Institutions, and the wide basis on which the conference is founded should help to foster a useful breadth of outlook in those young scientists and engineers who choose to make their career in atomic energy, either with the United Kingdom Atomic Energy Authority or in private industry. As time goes on, the implementation of the nuclear power programme will lead to there being a large body of experience in design in private industry, and of experience in reactor operation in the C.E.A. These various organisations will no doubt develop their own ideas on nuclear engineering, on the composition of design teams, and on the kind of engineer or scientist that is required for the class of work they are interested in. Inevitably this will lead back to the question of training of nuclear engineers, and the B.N.E.C. would seem to be an obvious body to co-ordinate such views. In the United States the Nuclear Engineering Division of the American Institute of Chemical Engineers, which has now been in existence for two years, has as one of its objectives the co-ordination of educational activities in nuclear engineering between Governmental agencies, industry and academic institutions, and it has been able to sponsor a number of useful discussions on the subject of education and training.

For atomic energy to be developed rapidly, engineers and scientists must become accustomed to getting together to discuss problems of common interest, and the formation of the B.N.E.C. is a major step towards this. Its success will depend entirely on how well it meets this need. Not being a body with any professional status, it will only gain support for its meetings and for its journal if it can prove by its choice of papers and by its other activities that it is taking a leading part in spreading knowledge of nuclear engineering in this country. It cannot, however, succeed without co-operation from the members of the founding professional bodies. Nothing will be gained if meetings sponsored by, say, the Institution of Mechanical Engineers, are attended only by members of that Institution. Sir Christopher Hinton has on a number of occasions recently drawn a parallel between the kind of power reactor that is at present being built and the slow speed reciprocating steam engine. It is also of interest to recall that in the early development of that engine, James Watt, in attempting to improve and per-

fect his engine, took a keen interest in scientific experiments and undoubtedly profited from the discussions he had with Joseph Priestley and other chemists of his day. A weakness in the composition of the B.N.E.C. is the absence of any metallurgical representation. Many of the possible developments in nuclear reactor design are likely to depend on the ability of the metallurgists to find suitable materials of construction, and we should have thought that the conference would have offered an excellent forum in which the metallurgist could get across to the engineer who, after all, is the user, the properties and limitations of the metals and alloys he has been investigating. Satisfactory design can only emerge when the designer has a thorough understanding of the materials he is using, and in nuclear reactors not only can we expect familiar metals to be used under unusual conditions, but entirely new alloys and materials of construction are likely to be employed. So far, the B.N.E.C. has not given many details of the subjects it intends to cover with its papers, but we should like to see the conference include several papers each year devoted to metallurgical developments, fabrication techniques and the behaviour of materials when exposed to radiation.

MORE RATIONAL DESIGN IN STRUCTURAL STEEL

We print on page 834 of this issue abstracts from a paper given last week by Dr. Faber in which a new method of design for composite steel and concrete stanchions is set out. Considerable potential savings in steel are claimed for the method, and it is shown how, in the author's opinion, it could be incorporated in the relevant British Standard for structural steelwork design. Such a plea for more rational design in structural steel is, we think, particularly welcome. Although research and development applied to structural steel have not been by any means absent over the past few years (we immediately think of developments with the plastic theory, and with prestressed steel, cold-formed sections and tubular steel), there is still the distinct impression that structural steel is losing ground to its chief competitors, reinforced and prestressed concrete, and is becoming the more expensive alternative in certain cases.

The heart of the problem lies in the design of multi-storey frames, whereas most of the recent advances in structural steel usage relate to other forms of structure. Conservatism in multi-storey designs may be due, as has often been pointed out, to the hampering effects of regulations covering fire protection, structural adequacy, and so forth. But whatever the cause, the design of a multi-storey steel frame remains somewhat unscientific and extravagant. It is a problem not yet solved by that *tour-de-force* of British civil engineering research—the plastic theory. By coincidence, a paper on stanchion design by plastic methods ("The Stanchion Problem in Framed Structures Designed According to Ultimate Carrying Capacity," by M. R. Horne) was given at the Institution of Civil Engineers on the same day as Dr. Faber's paper was read, and a quotation from its conclusions is not without relevance. "It will be seen from this discussion," Dr. Horne stated, "that a complete design method for multi-storey buildings is not yet available. At the same time, it is believed that, with the knowledge now available, it should be possible to design multi-storey, multi-bay frames provided the designer is prepared to use plastic theory in conjunction with reasonable approximations derived from elastic theory where appropriate. With growing experience of such intelligent applications of existing knowledge it should be possible to develop an economical yet straightforward design method."

One other significant line of inquiry should also be noted. Lacking a developed plastic design method for immediate use, the Building Research Station has concentrated its researches on how to make economies with existing design methods. We commented on the Station's work and on this particular problem of steel-frame design in a leading article in THE ENGINEER of July 22nd last, and some of the design procedures advocated by the Station were also described in that issue. By taking measurements on actual structures, and carrying out full-scale tests, the Building Research Station has demonstrated that steel frames are, in fact, stressed to a lower value than that computed by normal elastic design, and that savings can be made relatively simply. The problem of the concrete-encased stanchion has been one of several researches on steel-framed structures at the Station, but in the published results which we have seen, the conclusions reached on that subject have not been pressed so ruthlessly to their ultimate conclusion, as have Dr. Faber's researches. That might be expected, for Dr. Faber used the 1250-ton testing machine at Dorman Long's works and such a large machine has not been available at the Building Research Station. "Only on a machine of such size can these full-size tests be properly conducted," Dr. Faber stated. "It is no doubt true that a lot of valuable information can be obtained on small test pieces in small test machines, but many people will feel more convinced if they see full-size specimens broken under loads approaching 1000 tons." The examples quoted in the paper, and reproduced in this issue, indicate the potential savings in steel which can be made, and point to the usefulness of a composite method of construction, in which a light steel frame can be used in conjunction with a relatively massive concrete encasement, added later, to carry all the dead loads of the cladding and finishing materials of the building. There is a refreshing directness in the presentation of Dr. Faber's research :

> "Turn him to any cause of policy
> The Gordian knot of it he will unloose
> Familiar as his garter."

We hasten to add that more work is needed to elaborate his results, and take account, for instance, of eccentric loading. And, as we have indicated, there are many allied problems in steel design, needing similar treatment. We hope they will soon receive it, for the forests of steel which are a common sight in London and other cities at present are, we humbly suggest, rather too profuse in their growth, and could be pruned here and there with advantage.

A LUBRICATION GROUP AT THE "MECHANICALS"

In our last issue we were able to include a short note recording the intention of the Institution of Mechanical Engineers to set up a Lubrication Group as an addition to the number of other specialist groups already organised in that Institution. We now learn that besides Dr. Clayton, who has accepted an invitation to be chairman, Professor Hugh Ford, Professor Saunders and Dr. C. G. Williams have agreed to serve on its committee. The intention of the Council in setting up groups within the Institution has been to bring to an end the creation of new and independent specialist societies whose objects could well be covered by the major body. That it is better to have such groups under the wing of the Institution than to accept a multiplication of small societies seems to us self-evident. For the major Institution can provide all the accommodation and facilities that a specialist group requires. It is true independence is lost. But considerable autonomy can be granted and there is the further advantage that because group meetings are open to all Institution members discussions can be more broadly based. Furthermore, joint meetings with other groups to discuss papers of interest to both are far more easily arranged than joint meetings between independent small societies. The group is, too, relieved of that financial stringency that so often afflicts small bodies. In the present instance the Institution appears to have acted just in time to prevent the formation of a "splinter" society. Whether, of course, that society would, in fact, have been formed it is now impossible to say; but certainly the first none-too-hesitant steps had been taken towards its formation. We understand that, consequent upon the Institution's action, the project has been dropped and we confidently hope that the Council will invite some of the prime movers of that project to serve on the committee of the new group.

A Seven Day Journal

Research at City and Guilds College

A REPORT on research work at the City and Guilds College, South Kensington, over the period 1952–55, has been published. The report is intended as a general account of research work at the college, so some work of a specialised nature which, it was considered, would be difficult to describe has been omitted. Nonetheless, a fairly representative account of the various departments' work is given, grouped under the headings of aeronautics, chemical engineering, civil engineering, electrical engineering, mechanical engineering, and mathematics. Accounts of many of the items of research mentioned have been published from time to time, and many of them are generally well known to engineers directly concerned with the particular branch of study concerned. The total amount of work under all six headings is, however, of considerable scope and importance. Nearly half the volume is given over to descriptions of civil engineering researches, into subjects of basic importance in structural engineering, soil mechanics, hydraulics and public health engineering.

National Council for Awards in Technology

IN a written Parliamentary reply on December 1st, Sir David Eccles, Minister of Education, announced the names of five members of the new National Council for Awards in Technology, of which Lord Hives was appointed chairman in July. The council is to hold its first meeting on December 19th. The five members appointed by the Minister are Sir Harold Roxbee Cox, Sir Arnold Hall, Dr. Willis Jackson, Dr. Idris Jones, and Mr. E. L. Russell. It will be recalled that the council is being constituted on the advice of the National Advisory Council on Education for Industry and Commerce. Its function will be to create and administer awards in technology which will have a national currency and will be available to students in technical colleges who successfully complete higher technological courses approved by the council. These awards will be designed to provide at the first level an educational qualification comparable in standard to a university first degree. Appropriate post-graduate awards may be established later. The council will be an independent self-governing body operating under a Deed of Trust and will consist of the five members now appointed by the Minister of Education, and of three appointed from their members by each of two Boards of Studies. Of the five members appointed by the Minister, four are chosen for their eminence and distinction in the field of technology and one for his knowledge of local education authority administration. Of the three appointed by each Board, at least one will be a member of the teaching staff of a technical college. The Board of Studies in Engineering at present consists of twenty-seven members, of whom five are nominated by the Minister to represent industry and other fields, including the universities, and twenty-two by professional and other associations. The Board of Studies in technologies other than engineering comprises twenty-five members, five nominated by the Minister on a similar basis and the remainder by professional and other bodies. These Boards of Studies will be meeting for the first time on December 15th to elect representatives to serve on the council. The Boards will be responsible to the council for all matters concerned with the approval of courses, including the curricula and syllabuses of courses proposed for the awards, and in particular the standard of the college work in pure science and in technologies related to the courses for which approval is sought; the standard of admission to the courses and of the final examinations; the qualifications of the teachers; the accommodation and equipment, and the conditions for the conduct of the examinations. The Ministry of Education has emphasised that the council will not be an external examining body, but a body which will ensure for those seeking the award that the conditions under which the colleges propose to teach and examine the students are satisfactory. Where these conditions are met, the colleges will be recognised for the courses concerned and for the award they make to students who complete the courses successfully.

Launch of the "Spyros Niarchos"

ON Friday of last week Lady Weeks, the wife of General Sir Ronald Weeks, the chairman of Vickers, Ltd., gave the name of "Spyros Niarchos" to the oil tanker which was launched from the Barrow yard of Vickers-Armstrongs, Ltd. This ship, which has a deadweight of 47,750 tons, is believed to be the largest oil tanker in the world and is the ninth of the first group of ten orders placed with the builders by Mr. Niarchos. The following are the main particulars of the ship: length overall 757ft, length between perpendiculars 725ft, breadth moulded 97ft 2in, depth moulded 52ft, maximum draught 37ft 9in, sea speed at 36ft draught is 17 knots. Welded construction has been employed throughout except for certain seams in the bottom shell, at the bilge, at the sheerstrake and on the upper deck, and twin longitudinal bulkheads in association with transverse bulkheads divide the cargo space into thirty-three oil compartments. For handling the oil cargo there are four turbine-driven horizontal centrifugal pumps, each having a capacity of 1000 tons per hour, and three steam-driven vertical stripping pumps, each of 150 tons per hour capacity. Four 14in O.D. cargo oil pipelines are fitted in the tanks and on deck and there is a 6in ring main stripping line. For supplying the necessary power to drive the ship there is a single set of double reduction geared turbines having an impulse h.p. ahead turbine and an impulse-reaction double-flow l.p. ahead turbine and capable of developing a service power of 18,000 s.h.p. and a maximum power of 20,000 s.h.p. at 101·4 and 105 propeller revolutions per minute, respectively. The "Novoston" propeller is of five-bladed design. Three Foster-Wheeler "D" water-tube boilers, burning oil fuel under forced draught, provide steam at 600 lb per square inch and 800 deg. Fah. Electrical power for the auxiliary machinery and ship's services is generated by two 850kW, 450V, three-phase, 60 c/s turbo-alternators, each capable of taking the full load, while for stand-by and emergency purposes there is a diesel-driven 150kW alternator.

Institution of Water Engineers

THE sixtieth winter general meeting of the Institution of Water Engineers was held last week on December 2nd, at the Institution of Civil Engineers' building in Great George Street, Westminster. Three papers were presented for discussion at the meeting, namely, "The Construction of a Service Reservoir Using Colloidal Cement Grout Concrete," by H. Seddon; "The Water Engineer and Cathodic Protection," by K. A. Spencer; and "Some Recent Works in Baghdad," by G. Smethurst. Mr. Seddon described in some detail, in his paper, the constructional methods used to build the Higher Berse covered service reservoir of the Wrexham and East Denbighshire Water Company; the reservoir has a capacity of just over 2 m.g. and he thought that it was the first one to be built with colloidal concrete in this country. Colloidal grout concrete was eminently suitable for such work, he considered, where only a small labour force was available, and it was not desired to spend large capital sums on plant. Such concrete was impermeable, a very essential quality for reservoir construction, and the placing of coarse aggregate could go ahead at any speed, depending on the labour available. Large areas had been laid without expansion or contraction joints, without any apparent cracking. A reasonably cheap reservoir had been obtained, Mr. Seddon stated, but economies could be obtained by varying certain details, depending on the site chosen, although still adhering to the basic principles. Mr. Spencer's paper on cathodic protection described the practical aspects of bituminous coatings and cathodic protection for buried steel pipelines. The technical and economic aspects of these coatings were both discussed. The author concluded that the cost of protecting an uncoated pipeline by cathodic protection was high, and he strongly recommended that new pipelines should be protected with a good hot-applied bitumen coating and any bare metal thereafter covered by cathodic protection, as the optimum economic advantage was obtained by using both methods. Each case of cathodic protection, however, needed individual study.

Mr. Glenn L. Martin

WE regret to record the death of Mr. Glenn Luther Martin, which occurred at Baltimore, on Sunday last, December 4th. Mr. Martin, who was sixty-nine, built his first powered aircraft in 1908, when he was a garage owner, having already experimented with kites and gliders. It was a biplane with a Ford engine. Shortly afterwards, he organised one of the earliest aircraft factories, and in 1917 the Glenn L. Martin Company was founded at Cleveland, Ohio. With Martin there worked Lawrence D. Bell and Donald W. Douglas, founders of the firms that bear their names to-day. The firm's Liberty-engined bomber-biplane was regarded as the first successful twin-engined design in the U.S.A., and was unusually fast for a contemporary heavy bomber. Fifteen years later another twin-engined bomber, an all-metal monoplane, left the Baltimore, Maryland, factory, marking a new level of performance for bomber aircraft. Other twin-engined aircraft, the "Maryland," "Baltimore" and "Marauder," saw service with the R.A.F. in World War II. An early interest of Martin's was the seaplane, and a four-engined flying boat with sponsons became widely known in the Pan-American "Clipper" fleet. Later flying boats were the wartime "Mariner" and the "Mars." All these aircraft were designed and built while Martin was controlling the company: in 1949 he relinquished the position of manager, but remained on the board until his death.

Characteristics of Six-Phase Rectifiers from No-Load to Short Circuit

EFFECT OF DELAYED COMMUTATION AND CLOSING STEPS

By D. R. SMITH

The usual assumption underlying the theory of multi-phase rectifiers, that the periods of commutation do not overlap, can be invalidated under conditions of very high overloads or high a.c. reactance. Equations have been developed to allow for the effect of overlapping commutations, but these solutions appear to have been limited to rectifiers having only primary reactance and working without delayed commutation. Here more general equations are derived, making allowance for primary and secondary reactance, for all values of phase delay and for closing-steps.

THE basis of traditional rectifier theory is the assumption that the periods of commutation do not overlap ; that is, each commutation ends before the next one is due to begin. Thus, the voltage effective in the commutating circuit is simply the open circuit transformer secondary line-to-line voltage. In the case of six-phase rectifiers there are six commutations per cycle of the a.c. supply. Thus, if the commutation angle is less than 60 electrical degrees, the assumption that commutations do not overlap is correct. In practice this covers most rectifier applications. However, where exceptional overloads or high a.c. reactance are met, the commutation angle may exceed 60 deg. When this happens the inductive coupling between two circuits commutating simultaneously has the effect of increasing the voltage regulation and commutation angle above the values predicted by traditional theory.

This phenomenon has been recognised for some time and equations have been derived taking into account the effect of overlapping commutations.[1,2] However, as far as is known, these solutions have been limited to rectifiers having only primary reactance and operating without delayed commutation. In the present article equations are derived for the more general case in which both primary and secondary a.c. reactance are present and for all values of phase delay, down to short circuit. In addition the solution has been extended to include the case of the contact rectifier, in which saturating "comreactors" in the a.c. phases produce a low-current closing-step at the start of each conduction period.[3] The main purpose of the closing-step is to delay the growth of current through the closing contact until firm contact pressure has been established.

The closing-step has also been used with contact rectifiers[4] as a method of delaying commutation for d.c. voltage control, and has also been proposed for the same purpose with germanium rectifiers.[5] Where a closing-step is present, traditional theory breaks down when the sum of the closing-step and commutation angle equals 60 deg. Thus for a closing-step of 45 deg., which gives a d.c. voltage reduction of about 30 per cent, operation in mode 2 begins when $u=15$ deg. For usual values of a.c. reactance this occurs at less than full load.

Equivalent Circuit

The connections dealt with in this article are those six-phase connections in which the basic conduction period is 120 deg. The most important of these are the three-phase bridge connections and the six-phase double-star connection.

It is well known that the reactance associated with the a.c. side of a three-phase bridge rectifier is equivalent to three reactances in the a.c. lines. The case of the six-phase double-star connection is complicated by the presence of secondary reactance, i.e. reactance associated with one secondary transformer winding but not the other and vice versa. The equivalent circuit then becomes as shown in Fig. 1. If, as is usual, the secondary windings are interwound, $X_s=0$ and the equivalent circuit reduces to the three reactances X_p.

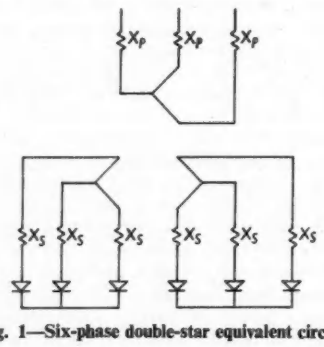

Fig. 1—Six-phase double-star equivalent circuit

In the contact rectifier the comreactors increase the circuit reactance. For connections employing a separate reactor in series with each contact this extra reactance is secondary reactance and requires modification of the equivalent circuit in the case of the bridge rectifier, as shown in Fig. 2. For the six-phase double-star connection the effect of the reactance of the comreactors is to increase the value of X_s in Fig. 1.

It will be noted that in Fig. 2 X_p the primary reactance is shown referred to the secondary side of the transformer. This is to emphasise the distinction between primary and secondary reactance ; the former being reactance common to both negative (Group I) and positive (Group II) sides of the bridge, the latter reactance affecting the two sides separately.

The comreactors are treated as two separate reactors in series. One of them is an ideal saturating reactor with a rectangular *B-H* characteristic, the other is a linear reactor equal to the air-cored reactance of the comreactors. Since the former reactance is zero always unless the current is zero, it is only the latter which adds to the commutating reactance. Hence the value of X_s to be used in Fig. 2 is the reactance of a reactor in all respects similar to the comreactor, but having an air core.

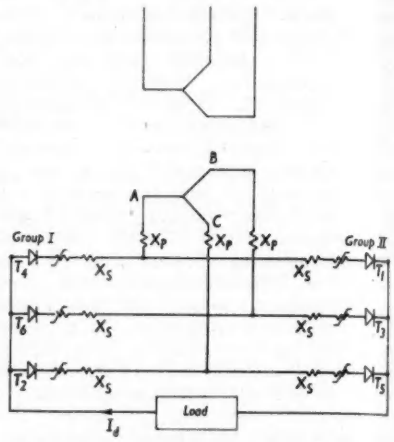

Fig. 2—Full-wave bridge rectifier equivalent circuit

The closing-step results from the volt-seconds required to saturate the comreactor in the incoming phase before commutation can begin. The voltseconds absorbed remain constant throughout all modes of operation. It follows, therefore, that the duration of the closing-step will vary through the different modes because of the changing waveform of the secondary voltage.

Qualitative Discussion

Consider the six-phase, double way rectifier shown in Fig. 2. This rectifier has primary reactance X_p, due to the transformer and a.c. supply reactance, and secondary reactance X_s, due to the comreactors and any other reactance not common to both group I and group II. The rectifying valve elements are T_1 to T_6 in the diagram.

Commutation between two phases normally begins at the instant of intersection of the incoming and outgoing phase voltages. At no-load these voltages vary sinusoidally with time, but when the rectifier is carrying load they are distorted by commutation notches. If the period of commutation exceeds 60 deg. each commutation is influenced by the voltage notches produced by the preceding and following commutations.

Consider, for example, commutation from T_5 to T_1 of group II in Fig. 2. The preceding commutation is from T_4 to T_6 of group I. Reactance X_p in phase *A* is common to both these commutations, and the voltage induced in it by the commutation from T_4 to T_6 opposes the voltage e_{ca} producing commutation from T_5 to T_1. Thus, at the instant when the latter is due to begin, the voltage across T_1 is still negative and falls to zero α_{pm} radians later.

Commutation from T_5 to T_1 cannot begin until the voltage across T_1 reverses direction. This reversal will occur either after a delay

List of Symbols

V_{d_0}—Theoretical no-load d.c. voltage for zero delay and without closing-step, with interphase transformer (if any) fully magnetised.
V_d—Actual value of d.c. voltage.
E_s—R.M.S. secondary phase-to-neutral voltage at no-load.
e_{ab}, e_{bc}, e_{ca}—Instantaneous secondary line-to-line voltages at no-load.
$e'_{ab}, e'_{bc}, e'_{ca}$—Instantaneous line-to-line voltages, measured between valve elements T_1 T_2, &c., when load current is being commutated.
I_d—D.c. load current, amperes.
I_s—Current change in commutating circuit during commutation, amperes.
I'_s—Current change in commutating circuit of earlier commutation during period of overlapping in modes 3 and 4, amperes.
I''_s—Current change in commutating circuit of later commutation during overlapping in mode 4, amperes.
T_1, &c.—Instantaneous value of current in valve element T_1, &c., amperes.
α—Angle by which the start of commutation (or, if present, closing-step) is delayed in mode 1, radian.
α_p—Inherent delay angle produced in mode 2, radian.
α_{pm}—Maximum value of α_p, defined by Equation 7(a) radian.
α_e—Angle equal to α or α_{pm}, whichever is the greater, radian.
ψ—Duration of closing-step, radian.
ψ_0—Value of ψ in mode 1 when $\alpha=0$.
u—Commutation angle, measured from the end of closing-step to the end of commutation, radian.
ϕ—Total overlap angle $\psi+u$.
X_p—Primary reactance referred to secondary lines, i.e. reactance associated with both three-phase rectifier groups, all reactances present, ohms.
X_s—Secondary reactance referred to secondary lines, i.e. reactance associated with one or other three-phase group, all reactances present, ohms.
X_c—Reactance of commutating circuit, measured between valve elements T_1, T_2, &c., all reactance present, ohms.
f—Frequency of a.c. supply, cycles per second.
ω—$2\pi f$.
k—Ratio of primary to total reactance, $\frac{X_p}{X_p+X_s}$.
K—$\frac{1}{2}\sqrt{4-2k+k^2}$.

of α_{pm} or when commutation from T_4 to T_6 ends, whichever happens first.

Therefore, as the load on the rectifier is raised the commutation angle u increases until it equals 60 deg. With further increase in load the start of each commutation is delayed α_p due to the voltages induced by the commutation before it. Each commutation begins at the instant the previous commutation ends, so no overlapping occurs and u remains equal to 60 deg. Operation when u is constant and α_p increases with load is referred to as mode 2, as distinct from normal operation in mode 1.

When $\alpha_p=\alpha_{pm}$ commutation begins even though the preceding commutation is still in progress. Thereafter commutations overlap and u increases with load while the delay remains equal to α_{pm}. Operation under these conditions is referred to as mode 3.

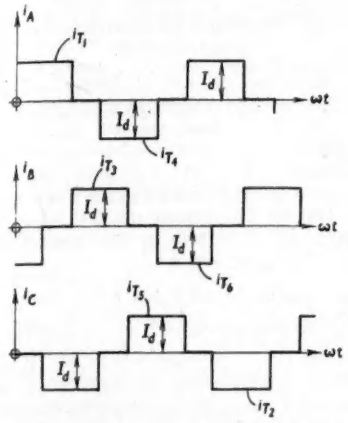

Fig. 3—Valve currents for circuit of Fig. 2

Effect of Grid Control.—Grid-control of mercury arc rectifiers, or the equivalent with other rectifiers, is commonly used as a means of d.c. voltage control. The rectifier then operates with delay α in mode 1. The main effect of grid control is that the value of load at which operation changes from one mode to the next increases with α. However, if $\alpha>\alpha_{pm}$ operation in mode 2 is not possible, but changes direct from mode 1 to mode 3 and vice versa.

Closing-Step.—In the case of the contact rectifier each commutation is preceded by a low-current closing-step. This occurs while the commutating voltage is absorbed in reversing the flux in the comreactor in the incoming phase. These reactors have a very high inductance when unsaturated so that the current through them remains more or less constant and near zero. A definite predetermined number of voltseconds are required from the commutating voltage to saturate the comreactor.

As the commutating voltage is blocked by the valve elements T_1, T_2, T_3, &c., until the voltage becomes positive, the closing-steps cannot begin until this voltage reverses. When the total overlap angle $\phi=60$ deg., the voltage notch produced by the preceding commutation will delay the start of each closing-step by α_p in exactly the same way as in the more straightforward case described earlier.

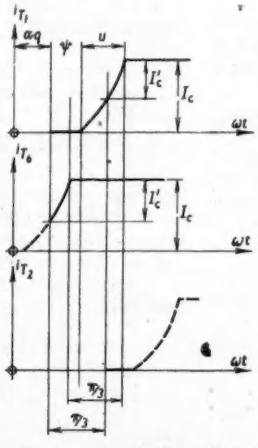

Fig. 4—Operation in mode 3a

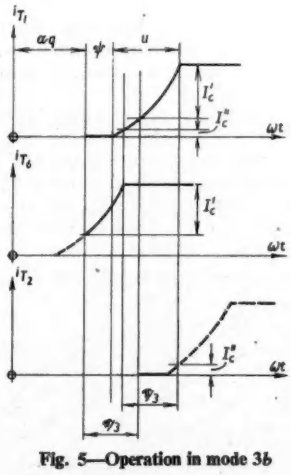

Fig. 5—Operation in mode 3b

It is necessary to divide operation in mode 3 into two parts when closing-steps are present. The inherent delay in mode 3 is always α_{pm}. In mode 3*a* each commutation overlaps only the following closing-step. Operation changes to mode 3*b* when the overlap extends beyond the closing-step into the following commutation.

Derivation of Characteristics

The particular case investigated is the six-phase, double way connection (full-wave bridge). Sufficient d.c. inductance is assumed to produce a d.c. output without ripple. The final expressions are in a form applicable to the six-phase, double star connection.

The no-load transformer secondary line-to-line voltages are :—

$$e_{ca}=\sqrt{6}E_s\sin\omega t$$

$$e_{ab}=\sqrt{6}E_s\sin\left(\omega t+\frac{2\pi}{3}\right)$$

$$e_{bc}=\sqrt{6}E_s\sin\left(\omega t+\frac{4\pi}{3}\right) \quad . \; . \; . \quad (1)$$

The rectifying valves are shown as T_1 to T_6 in Fig. 2. The time scale in equations (1) has been selected so that commutation from T_5 to T_1 normally begins at $\omega t=0$. The valve currents are shown in Fig. 3.

The rectifier is operating with delay α in mode 1, so that the closing-step preceding commutation from T_5 to T_1 begins at $\omega t=\alpha$ in this mode. In the higher modes the commutating voltage, e'_{ca}, is distorted by the commutation from T_4 to T_6, and e'_{ca} may still be negative (i.e. in the direction opposing commutation from T_5 to T_1) when $\omega t=\alpha$. The negative voltage is blocked by T_1 so that the closing-step for T_1 does not start until e'_{ca} becomes positive.

The d.c. volt-drop is calculated from the voltseconds lost in the phase of T_1 during its nominal 120 deg. conduction period from $\omega t=0$ to $\omega t=\frac{2\pi}{3}$, due to the delay α, the closing-step ψ, the commutation from T_5 to T_1, and that part of the commutation from T_4 to T_6 occurring during the period from $\omega t=\alpha$ to $\omega t=\frac{2\pi}{3}$.

The total overlap-angle ϕ is calculated by equating the voltseconds applied to the commutating circuit by the transformer voltage e_{ca} to the voltseconds induced in the circuit during the interval $\omega t=\alpha$ to $\omega t=\alpha+\phi$ by commutations T_5 to T_1, T_4 to T_6 and T_6 to T_2.

The closing-steps are due to saturating reactance in the incoming-phase. This closing-step reactance is defined quantitatively in terms of the voltseconds required to saturate the comreactors before commutation can begin. The duration of the closing-step will vary with delay and with the mode in which the rectifier operates. Its value in mode 1 when $\alpha=0$ is ψ_0.

Hence :

Closing-step voltseconds

$$=\int_0^{\psi_0}\sqrt{6}E_s\sin\omega t dt$$

$$=\frac{1}{\omega}\sqrt{6}E_s(1-\cos\psi_0) \quad . \; . \quad (2)$$

Mode 1.—This is the normal mode of operation in which the commutations in group I of Fig. 2 have no influence on the commutations in group II and vice versa.

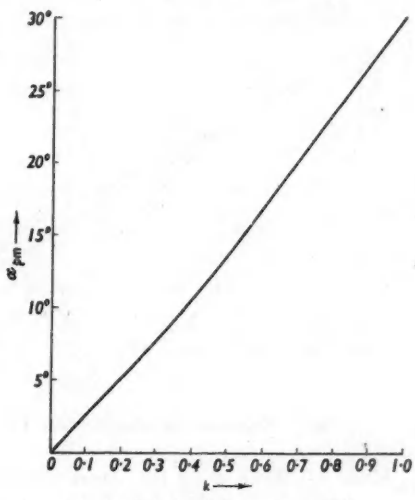

Fig. 6—Relation between α_{pm} and k

Considering the closing-step and commutation period for commutation from T_5 to T_1 :

$$\int_\alpha^{\alpha+\psi}\sqrt{6}E_s\sin\omega t d\omega t=\sqrt{6}E_s(1-\cos\psi_0)$$

Hence,

$$\cos\alpha-\cos(\alpha+\psi)=1-\cos\psi_0 \; . \; . \quad (3)$$

also,

$$\int_{\alpha+\psi}^{\alpha+\phi}\sqrt{6}E_s\sin\omega t d\omega t=I_cX_c$$

$$\sqrt{6}E_s[\cos(\alpha+\psi)-\cos(\alpha+\phi)]=I_cX_c$$

substituting from equation (3),

$$\frac{I_cX_c}{\sqrt{6}E_s}=\cos\alpha-\cos(\alpha+\phi)-(1-\cos\psi_0) \; . \quad (4)$$

Consider next the volt-radians induced in the T_1 phase from $\omega t=0$ to $\omega t=\frac{2\pi}{3}$.

Volt-radians lost due to delayed commutation $=\sqrt{6}E_s(1-\cos\alpha)$.

Volt-radians absorbed in closing-step $=\sqrt{6}E_s(1-\cos\psi_0)$.

Volt-radians absorbed in commutation T_5 to $T_1=\frac{1}{2}I_cX_c$.

Total loss of volt-radians in period $=\sqrt{6}E_s(2-\cos\alpha-\cos\psi_0)+\frac{1}{2}I_cX_c$.

Note that although commutation T_6 to T_2 takes place during this period it causes no current change and therefore no voltage in phase A.

The d.c. voltage drop is obtained by multiplying the total voltseconds lost by the number of commutations per cycle and the frequency of the a.c. supply.

$$V_{d_0}-V_d=\frac{6f}{\omega}[\sqrt{6}E_s(2-\cos\alpha-\cos\psi_0)+\tfrac{1}{2}I_cX_c].$$

Now,

$$V_{d_0}=\frac{3\sqrt{6}}{\pi}E_s.$$

Hence,

$$\frac{V_d}{V_{d_0}}=\cos\alpha-(1-\cos\psi_0)-\frac{1}{2\sqrt{6}E_s}\,I_cX_c \quad . \quad (5)$$

Operation changes to mode 2 when $\phi=\frac{\pi}{3}$, hence from equation (4) the condition for operation in mode 1 is :

$$0<\frac{I_cX_c}{\sqrt{6}E_s}<\sin\left(\alpha+\frac{\pi}{6}\right)-(1-\cos\psi_0) \quad . \quad (6)$$

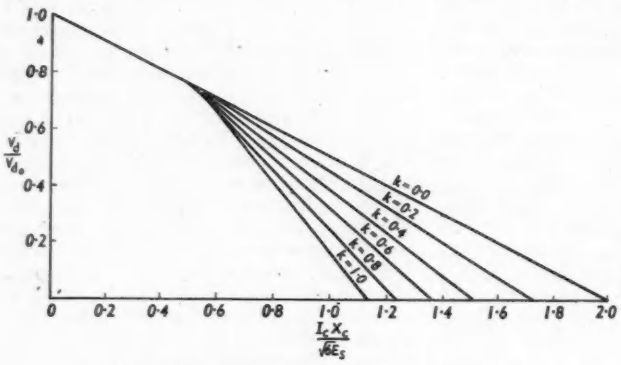

Fig. 7—Regulation for different values of k, $\alpha=0$ and $\psi_0=0$

Mode 2.—When $\phi=\frac{\pi}{3}$ the commutation T_4 to T_6, for example, is still in progress at $\omega t=\alpha$ when the closing-step of T_1 is due to begin. The voltage induced in the commutating circuit of T_5-T_1 by commutation T_4 to T_6 is :

$$e=\frac{X_p}{\omega}\cdot\frac{d}{dt}(i_{ab})$$

where i_{ab} = instantaneous value of current commutating from T_4 to T_6.

$$e=\frac{X_p}{X_c}\cdot e_{ab}$$

substituting from equations (1) and putting

$$\frac{X_p}{X_c}=\frac{X_p}{2(X_p+X_s)}=\frac{k}{2},$$

$$e=\frac{k}{2}\sqrt{6}E_s\sin\left(\omega t+\frac{2\pi}{3}\right).$$

The resultant commutating voltage is obtained by subtracting e from e_{ca} :

$$e'_{ca}=\sqrt{6}E_s\sin\omega t-\sqrt{6}E_s\frac{k}{2}\sin\left(\omega t+\frac{2\pi}{3}\right)$$

$$=\sqrt{6}E_sK\sin(\omega t-\alpha_{pm}) \quad . \quad . \quad . \quad (7)$$

Where

$$K=\tfrac{1}{2}\sqrt{(4-2k+k^2)}\text{ and }\tan\alpha_{pm}=\frac{\sqrt{3}k}{4-k}$$

. . . . . (7*a*)

Equation (7) shows that e'_{ca} is retarded by α_{pm} in phase with respect to e_{ca}. There are now two possible conditions to consider.

Case 1, $\alpha>\alpha_{pm}$.—If α is greater than α_{pm} then the commutating voltage e'_{ca} is positive at $\omega t=\alpha$ when the closing-step of T_1 is due to begin. There is therefore no operation in mode 2 if $\alpha>\alpha_{pm}$; operation changing direct from mode 1 to mode 3*a*.

Case 2, $\alpha<\alpha_{pm}$.—If α is less than α_{pm} the commutating voltage, e'_{ca}, will be negative at $\omega t=\alpha$ when the closing-step of T_1 is due to begin. Since this closing-step cannot begin until e'_{ca} is positive an inherent delay is produced, and the delay is increased to some value α_p. When $\omega t=\alpha_p$ the commutation T_4 to T_6 ends and immediately e'_{ac} changes to e_{ac} and the closing-step of T_1 begins. The start of commutation T_5 to T_1 is delayed α_p and from symmetry the end is delayed by an equal amount. Thus, during mode 2, the total overlap angle ϕ remains constant at $2\pi/3$ and the delay increases with increasing load.

It can be seen from equation (7) that when the load reaches a value at which $\alpha_p=\alpha_{pm}$, the commutating voltage e'_{ca} becomes positive irrespective of whether commutation T_4 to T_6 has ended or not. At this point no further increase in α_p occurs, and thereafter ϕ increases with load and operation changes to mode 3*a*.

The equations of operation in mode 2 are exactly similar to those in mode 1, except that α is replaced by α_p and $\phi=\pi/3$. The inherent delay α_p is the variable. The similarity of equations of mode 1 and 2 follows from the absence of the overlapping of commutation and closing-step, as occurs in modes 3*a* and 3*b*.

Therefore

$$\frac{I_cX_c}{\sqrt{6}E_s}=\cos\alpha_p-\cos(\alpha_p+\phi)-(1-\cos\psi_0)$$

. . . . . (8)

where $\alpha<\alpha_p<\alpha_{pm}$.

$$\frac{V_d}{V_{d_0}}=\cos\alpha_p-(1-\cos\psi_0)-\frac{1}{2}\frac{I_cX_c}{\sqrt{6}E_s}. \quad (9)$$

Conditions for operation in mode 2 are :

$$\sin\left(\alpha+\frac{\pi}{6}\right)-(1-\cos\psi_0)<\frac{I_cX_c}{\sqrt{6}E_s}<\sin\left(\alpha_{pm}+\frac{\pi}{6}\right)$$

$$-(1-\cos\psi_0) \quad . \quad . \quad . \quad . \quad (10)$$

also $\alpha<\alpha_{pm}$.

Operation in Mode 3*a*.—In mode 3*a* the commutations overlap the following closing-step. The delay remains constant and ϕ increases.

The delay during mode 3*a* will be either α or α_{pm}, whichever is the greater. This is because commutation cannot begin before $\omega t=\alpha$ because of the delay applied to the valve elements T_1 to T_6, neither can commutation begin before $\omega t=\alpha_{pm}$, since the commutating voltage is negative until this instant. To cover both cases we will define α_q as being equal to the greater of α or α_{pm}.

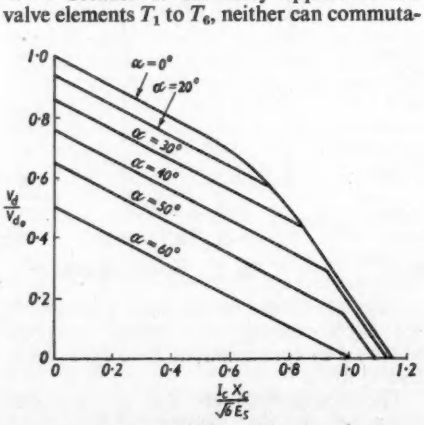

Fig. 8—Regulation for different values of α, $R=1$, $\psi_0=0$

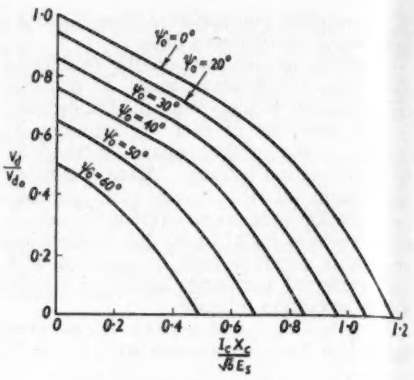

Fig. 9—Regulation for different values of ψ_0, $k=1$, $\alpha=0$

Consider first the period $\omega t=\alpha_q$ to $\omega t=\alpha_q+\phi$ during which T_5 commutates with T_1. During this period the following volt-radians are absorbed in the commutating circuit T_5–T_1, see Fig. 4 :

(*a*) Closing-step of $T_1=\sqrt{6}E_s(1-\cos\psi_0)$.

(*b*) Commutation from T_5 to $T_1=I_cX_c$.

(*c*) Part of commutation T_4 to $T_6=\frac{1}{2}kI'_cX_c$.

Note that only the closing-step of commutation T_6 to T_2 falls in this period and this produces no voltage in the commutating circuit T_5–T_1.

In Fig. 4, I'_c represents the current change in commutating circuit T_4 to T_6 during the period of the closing-step of T_1. From symmetry it also represents the current change in circuit T_5–T_1 during the closing-step of T_2.

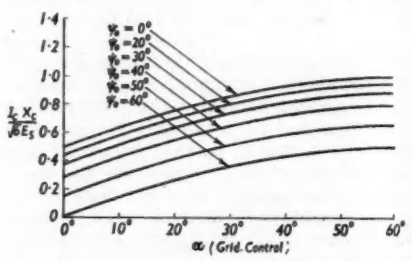

Fig. 10—Maximum load for operation in mode 1

The factor k in item (*c*) above arises because these volt-radians are due to primary reactance only.

Considering the time intervals in Fig. 4 :

$$\int_{\alpha_q}^{\alpha_q+\phi}\sqrt{6}E_s\sin\omega t\,d\omega t=\sqrt{6}E_s(1-\cos\psi_0)$$

$$+\frac{k}{2}I'_cX_c+I_cX_c$$

therefore,

$$\cos\alpha_q-\cos(\alpha_q+\phi)=1-\cos\psi_0$$

$$+\frac{k}{2}\frac{I'_cX_c}{\sqrt{6}E_s}+\frac{I_cX_c}{\sqrt{6}E_s},$$

also,

$$\int_{\alpha_q+\pi/3}^{\alpha_q+\phi}\sqrt{6}E_s\sin\omega t\,d\omega t=I'_cX_c,$$

therefore,

$$\cos\left(\alpha_q+\frac{\pi}{3}\right)-\cos(\alpha_q+\phi)=\frac{I'_cX_c}{\sqrt{6}E_s} \quad . \quad (11)$$

Substituting (11) in previous equation :

$$\frac{I_cX_c}{\sqrt{6}E_s}=\cos\alpha_q-\left(1-\frac{k}{2}\right)\cos(\alpha_q+\phi)-\frac{k}{2}\cos\left(\alpha_{pm}+\frac{\pi}{3}\right)-(1-\cos\psi_0)$$

or

$$\frac{I_cX_c}{\sqrt{6}E_s}=K\cos(\alpha_q-\alpha_{pm})-\left(1-\frac{k}{2}\right)\cos(\alpha_q+\phi)-(1-\cos\psi_0)\quad\ldots\quad(12)$$

Consider next the volt-radians induced in the phase of T_1 from $\omega t=0$ to $\omega t=\frac{2\pi}{3}$.

Volt-radians lost due to delayed commutation $=\sqrt{6}\,E_s(1-\cos\alpha_q)$.

Volt-radians absorbed in closing-step $=\sqrt{6}\,E_s(1-\cos\psi_0)$.

Volt-radians absorbed in commutation T_5 to $T_1=\frac{1}{2}I_cX_c$.

Volt-radians absorbed in commutation T_4 to $T_6=\frac{k}{2}I'_cX_c$.

Total loss of volt-seconds in period

$$=\sqrt{6}E_s(2-\cos\alpha_q-\cos\psi_0)+\tfrac{1}{2}I_cX_c+\frac{k}{2}I'_cX_c$$

Therefore,

$$\frac{V_d}{V_{d_0}}=\cos\alpha_q-(1-\cos\psi_0)-\frac{1}{2}\frac{I_cX_c}{\sqrt{6}E_s}-\frac{k}{2}\frac{I'_cX_c}{\sqrt{6}E_s}.$$

Substituting equations (11) and (12) for I'_c:

$$\frac{V_d}{V_{d_0}}=\frac{1}{2-k}\left(2\cos\alpha_q-k\cos\left(\alpha_q+\frac{\pi}{3}\right)-2(1-\cos\psi_0)-\frac{2+k}{2}\frac{I_cX_c}{\sqrt{6}E_s}\right)$$

or

$$\frac{V_d}{V_{d_0}}=\frac{1}{2-k}\left(2K\cos(\alpha_q-\alpha_{pm})-2(1-\cos\psi_0)-\frac{2+k}{2}\frac{I_cX_c}{\sqrt{6}E_s}\right)\quad\ldots\quad(13)$$

Condition for Operation in Mode 3a.—Operation changes from mode 3*a* to mode 3*b* when $u=\pi/3$, each commutation then completely overlaps the next closing-step and extends into the next commutation.

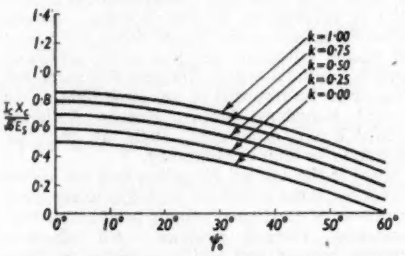

Fig. 11—Maximum load for operation in mode 2

To calculate the d.c. load at which operation changes from mode 3*a* to mode 3*b* it is necessary to obtain an expression for ψ.

Consider again the commutation of T_5 to T_1 and refer again to Fig. 4.

$$\int_{\alpha_q}^{\alpha_q+\psi}\sqrt{6}E_s\sin\omega t\,d\omega t=\sqrt{6}E_s(1-\cos\psi_0)+\frac{k}{2}I'_cX_c$$

Therefore

$$\cos\alpha_q-\cos(\alpha_q+\psi)=(1-\cos\psi_0)+\frac{k}{2}I'_cX_c,$$

also

$$\int_{\alpha_q+\pi/3}^{\alpha_q+\psi+u}\sqrt{6}E_s\sin\omega t\,d\omega t=I'_cX_c.$$

$$\cos\left(\alpha_q+\frac{\pi}{3}\right)-\cos(\alpha_q+\psi+u)=\frac{I'_cX_c}{\sqrt{6}E_s}.$$

Eliminating I'_c from these two equations :

$$\cos\alpha_q-\cos(\alpha_q+\psi)-(1-\cos\psi_0)=\frac{k}{2}\cos\left(\alpha_q+\frac{\pi}{3}\right)-\frac{k}{2}\cos(\alpha_q+\psi+u)$$

or

$$\cos(\alpha_q+\psi)-\frac{k}{2}\cos(\alpha_q+\psi+u)=K\cos(\alpha_q-\alpha_{pm})-(1-\cos\psi_0).$$

Putting $u=\pi/3$:

$$\cos\psi=\cos(\alpha_q-\alpha_{pm})-\frac{1}{K}(1-\cos\psi_0)\quad(14)$$

also putting $u=\pi/3$ in equation (10) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=K\cos(\alpha_q-\alpha_{pm})-\left(1-\frac{k}{2}\right)\cos\left(\alpha_q+\psi+\frac{\pi}{3}\right)-(1-\cos\psi_0).\quad(15)$$

Equations (14) and (15) give the values of ψ and I_c at which operation changes from mode 3*a* to mode 3*b*.

Operation in Mode 3b.—Fig. 5 shows the commutation of T_5 to T_1 when $u>\pi/3$. The commutation period can now be divided into three parts :

(1) $\alpha_q<\omega t<(\alpha_q+\phi-\pi/3)$, in which the current through T_5–T_1 changes by I''_c and that in T_6–T_6 by I'_c.

(2) $\alpha_q+\phi-\pi/3<\omega t<\alpha_q+\pi/3$, in which the current through T_5–T_1 changes by $(I_c-I'_c-I''_c)$.

(3) $\alpha_q+\pi/3<\omega t<\alpha_q+\phi$, in which the current through T_5–T_1 changes by I'_c and that through T_6–T_2 by I''_c.

Proceeding as for mode 3*a* :

$$\int_{\alpha_q}^{\alpha_q+\phi-\pi/3}\sqrt{6}E_s\sin\omega t\,d\omega t=\sqrt{6}E_s(1-\cos\psi_0)+I''_cX_c+\frac{k}{2}I'_cX_c$$

or,

$$\cos\alpha_q-\cos(\alpha_q+\phi-\pi/3)-(1\cos\psi_0)=\frac{I''_cX_c}{\sqrt{6}E_s}+\frac{k}{2}\frac{I'_cX_c}{\sqrt{6}E_s},$$

also

$$\int_{\alpha_q+\phi-\pi/3}^{\alpha_q+\pi/3}\sqrt{6}E_s\sin\omega t\,d\omega t=(I_c-I'_c-I''_c)X_c$$

Therefore,

$$\cos(\alpha_q+\phi-\pi/3)-\cos(\alpha_q+\pi/3)=(I_c-I'_c-I''_c)\frac{X_c}{\sqrt{6}E_s}$$

and

$$\int_{\alpha_q+\pi/3}^{\alpha_q+\phi}\sqrt{6}E_s\sin\omega t\,d\omega t=I'_cX_c+\frac{k}{2}I''_cX_c.$$

Therefore,

$$\cos(\alpha_q+\pi/3)-\cos(\alpha_q+\phi)=\frac{I'_cX_c}{\sqrt{6}E_s}+\frac{k}{2}\frac{I''_cX_c}{\sqrt{6}E_s}.$$

Solving these three equations for I_c, I'_c and I''_c :

$$\frac{I''_cX_c}{\sqrt{6}E_s}=\frac{4}{4-k^2}[K\cos(\alpha_q-\alpha_{pm})-K\cos(\alpha_q-\alpha_{pm}+\phi-\pi/3)-(1-\cos\psi_0)]\quad\ldots\quad(16)$$

and

$$\frac{I'_cX_c}{\sqrt{6}E_s}=\frac{4}{4-k^2}\left[K\cos(\alpha_q+\alpha_{pm}+\pi/3)-K\cos(\alpha_q+\alpha_{pm}+\phi)+\frac{k}{2}(1-\cos\psi_0)\right]\quad(17)$$

and

$$\frac{I_cX_c}{\sqrt{6}E_s}=\frac{2}{2+k}[K\cos(\alpha_q-\alpha_{pm})-K\cos(\alpha_q+\alpha_{pm}+\phi)-(1-\cos\psi_0)].\quad(18)$$

The d.c. voltage drop is given by the same terms as in mode 3*a*, hence :

$$\frac{V_d}{V_{d_0}}=\cos\alpha_q-(1-\cos\psi_0)-\frac{I_cX_c}{2\sqrt{6}E_s}-\frac{kI'_cX_c}{2\sqrt{6}E_s}.$$

Substituting equation (17 and 18) to eliminate I'_c :

$$\frac{V_d}{V_{d_0}}=\frac{1}{2-k}\left[2K\cos(\alpha_q-\alpha_{pm})-2(1-\cos\psi_0)-\frac{2+k}{2}\frac{I_cX_c}{\sqrt{6}E_s}\right]\quad\ldots\quad(19)$$

Note that equations (13) and (19) are identical. The equations for I_c are, however, not the same in mode 3*a* and mode 3*b*.

Summary of Characteristics

Mode 1.

Equation (4) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=\cos\alpha-\cos(\alpha+\phi)-(1-\cos\psi_0).$$

Equation (5) :

$$\frac{V_d}{V_{d_0}}=\cos\alpha-(1-\cos\psi_0)-\frac{1}{2}\frac{I_cX_c}{\sqrt{6}E_s}.$$

Valid for equation (6) :

$$0<\frac{I_cX_c}{\sqrt{6}E_s}<\sin\left(\alpha+\frac{\pi}{6}\right)-(1-\cos\psi_0).$$

Mode 2.

Equation (8) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=\cos\alpha_p-\cos(\alpha_p+\phi)-(1-\cos\psi_0).$$

Equation (9) :

$$\frac{V_d}{V_{d_0}}=\cos\alpha_p-(1-\cos\psi_0)-\frac{1}{2}\frac{I_cX_c}{\sqrt{6}E_s}.$$

Valid for equation (10) :

$$\sin\left(\alpha+\frac{\pi}{6}\right)-(1-\cos\psi_0)<\frac{I_cX_c}{\sqrt{6}E_s}<\sin\left(\alpha_{pm}+\frac{\pi}{6}\right)-(1-\cos\psi_0)\quad\text{also}\quad\alpha<\alpha_{pm}.$$

Mode 3*a*.

Equation (12) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=K\cos(\alpha_q-\alpha_{pm})-\left(1-\frac{k}{2}\right)\cos(\alpha_q+\phi)-(1-\cos\psi_0).$$

Equation (13) :

$$\frac{V_d}{V_{d_0}}=\frac{1}{2-k}\left(2K\cos(\alpha_q-\alpha_{pm})-2(1-\cos\psi_0)-\frac{2+k}{2}\frac{I_cX_c}{\sqrt{6}E_s}\right).$$

Transition to *mode* 3*b* when :

Equation (14) :

$$\cos\psi=\cos(\alpha_q-\alpha_{pm})-\frac{1}{K}(1-\cos\psi_0)$$

Equation (15) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=K\cos(\alpha_q-\alpha_{pm})-\left(1-\frac{k}{2}\right)\cos\left(\alpha_q+\psi+\frac{\pi}{3}\right)-(1-\cos\psi_0).$$

Mode 3*b*.

Equation (18) :

$$\frac{I_cX_c}{\sqrt{6}E_s}=\frac{2}{2+k}[K\cos(\alpha_q-\alpha_{pm})-K\cos(\alpha_q+\alpha_{pm}+\phi)-(1-\cos\psi_0)].$$

Equation (19):

$$\frac{V_d}{V_{d_0}}=\frac{1}{2-k}\left[2K\cos(\alpha_q-\alpha_{pm})-2(1-\cos\psi_0)-\frac{2+k}{2}\cdot\frac{I_cX_c}{\sqrt{6}E_s}\right].$$

Conclusions

Equations have been derived governing the relations between d.c. voltage, overlap angle and load, down to short circuit, for six-phase rectifiers having both primary and secondary reactance. The case solved is a general one including delayed commutation and closing-step.

It is not possible to express the complete solutions graphically as too many variables are involved. Graphs (Figs. 6–11) are included to show the dependence of d.c. voltage on load, delay, closing-step and ratio of primary to total reactance when these are varied two at a time. Solutions to particular cases can readily be plotted from the equations.

The general case including finite d.c. inductance has yet to be solved, though a solution for the case of zero d.c. inductance, and only primary a.c. reactance has been obtained when α and ψ are zero.[2]

Acknowledgments

The author wishes to thank Dr. J. C. Read for his suggestion that the subject matter should be presented as an article and to the B.T.H. Company for permitting publication.

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The Place of Nuclear Energy in United Kingdom Power Development*

By V. A. PASK, C.B.E., M.I.Mech.E., M.I.E.E., and J. C. DUCKWORTH, B.A.†

The first part of the lecture reviews the future requirements for electricity and indicates the minimum nuclear-power requirements if the import of fossil fuels is to be avoided. The factors justifying the decision to commence a nuclear power programme with graphite-moderated gas-cooled reactors are referred to and a comparison is made between the probable costs of generation of electricity at the early nuclear power stations and costs typical of coal-fired base-load stations planned for commissioning by 1962. *Possible future developments in the field of power reactors and their fuel supplies are referred to. The second part (not reproduced here) deals with the impact of base-load nuclear plant upon the design and operation of coal-fired plant, and upon schemes for pumped storage and the improvement of the night electricity load. It also discusses the question of the siting of nuclear power stations and the radical alteration brought about in the picture of future economic system development by the prospect of meeting a large part of the future electrical energy requirements by nuclear generation.*

IT will be recalled that a recent Government White Paper,‡ outlined a provisional programme for the construction of nuclear power plants. This envisaged the commissioning of twelve nuclear stations by 1965 with a total net output capacity of between 1500MW and 2000MW. A total net output capacity of 10,000–15,000MW by 1975 was also foreseen.

To appreciate the true significance of these figures they must be examined alongside the national electricity demands and total plant and energy requirements to which they correspond. In Table I the total plant and energy requirements for Great Britain as now estimated are shown for various levels of demand. Although each level of demand is labelled with a year it must be appreciated that the level shown for 1980/1, for instance, could well be reached five years earlier or five years later. The load factor, too, might increase faster than is assumed, but bearing in mind the social problems involved, the assumption given is probably the best that can be made at the present time.

TABLE I—*Total Power and Energy Requirements for Years* 1965/6 *to* 1980/1
ESTIMATED SEPTEMBER, 1955

	1965/6	1970/1	1975/6	1980/1
(1) Estimated peak demands, MW	34,500	43,500	55,500	70,500
(2) Total plant requirements, MW s.o. (sent out)	39,000	49,500	63,000	80,000
(3) Units sent out from generating stations, 10^9 kWh	136,000	176,000	229,000	295,000
(4) Units from hydro stations, 10^9 kWh	3,500	4,500	6,000	8,000
(5) Units required from thermal stations, 10^9 kWh	132,500	171,500	223,000	287,000

Table I (5) shows the units required from thermal generating plant and, if an upper limit of coal available from Britain's own coalfields is assumed, it is possible to assess the minimum nuclear plant requirement to avoid importing fossil fuels.

The assessment is made in Table II, where the allocation of home-produced coal for electricity supply is assumed to reach 60,000,000 tons per year by 1970 and thereafter to remain at this level. In judging this figure it must be remembered that at present 36·9 million tons of the total requirements of 40·9 million tons are being supplied by home production, and that the estimate of total requirements by 1965 is more than 60,000,000 tons per year

The units generated annually from this 60,000,000 tons per year of coal (Table II (2)) reflect the continual advance expected in the efficiency of coal-fired stations.

In Table II (1) the units required from thermal stations are repeated from Table I (5). The units obtainable from home-produced fuel are given in Table II (2) and by subtraction the units required from nuclear fission follow in (3). A maximum practical annual load factor of 75 per cent has been assumed for the nuclear plant; this gives in (4) the minimum capacity of nuclear plant required to generate (3). This figure rises from 3900MW in 1965/6 to 23,000MW, or rather more than the present total plant capacity, by 1980/1. Note that the requirement for nuclear plant (4) in 1965/6 is about twice the amount proposed in the Government White Paper; the balance will have to be met either by expansion of the nuclear plant programme or by additional plant burning imported fossil fuel. During the same period, the conventional steam plant capacity (6) must also be expected to rise, and by 1980 it will still be nearly two-and-a-half times the nuclear capacity.

Note from (5) that the nuclear load factor has begun to fall by 1980, indicating insufficient night and week-end load to keep the plant operating at maximum output. It also means that by that time all conventional steam plant should be operating on one and two-shift cycles for maximum economy.

This assessment has assumed that nuclear power will be able to compete with conventional plant and it would be as well at this stage to examine the prospects of achieving this.

Initial Costs

The initial nuclear plants will undoubtedly have a high capital cost, and the many future possibilities, some of them very attractive theoretically, have led some people to question the wisdom of becoming committed to a heavy programme based on the gas-cooled type of reactor. There are, however, excellent reasons for this. If the strain on conventional fuel resources is to be relieved fairly soon, it is essential to go ahead with the gas-cooled reactor, it is the only type which can be regarded as a commercial proposition at the moment. Several industrial groups in the United States have plans for more advanced reactors with scheduled completion dates within the next five years, but these must be regarded in the same light as the United Kingdom Atomic Energy Authority (U.K.A.E.A.) prototypes, such as the fast reactor to be built at Dounreay.

TABLE II—*Power and Energy Required from Nuclear Fission for Years* 1965/6 *to* 1980/1
ESTIMATED SEPTEMBER, 1955

	1965/6	1970/1	1975/6	1980/1
(1) Units required from thermal stations, 10^9 kWh	132,500	171,500	223,000	287,000
(2) Units obtained from home produced coal, 10^9kWh	107,000	131,000	136,500	140,500
(3) Units required from nuclear fission and/or imported fossil fuel, 10^9kWh	25,500	40,500	86,500	146,500
(4) Nuclear capacity required to provide (3), MW s.o.	3,900	6,000	13,000	23,000
(5) Assumed annual load factor of nuclear plant, per cent	75·0	75·0	75·0	73·0
(6) Capacity of coal-fired plant required, MW s.o	33,500	42,000	48,000	54,500
(7) Average load factor of coal-fired plant, per cent	36·4	35·6	32·4	29·4

Even if the United Kingdom had no annual fuel crises, there would still be a strong argument in favour of starting a reactor programme with gas-cooled thermal reactors. All advanced reactors require fuel which is richer in fissile material than natural uranium, but the only naturally occurring fissile material is the uranium 235 present in natural uranium. The gas-cooled reactor will operate on natural uranium and also produce fissile material in the shape of plutonium which can be separated from the irradiated uranium fuel element by chemical processes. By crediting this plutonium with a value less than the equivalent cost of uranium 235 from a gaseous diffusion plant, it is expected that electricity will be produced at an economic price.

Four teams of manufacturers are now working on the design of the first power reactors and the principal aim will be to obtain a reactor heat rating greater than that of Calder Hall. There is considerable scope for the ultimate improvement of the heat rating of the gas-cooled graphite-moderated reactor, but in view of the time available for the design of the first stations, fairly modest advances must be our aim at first. Some increase in fuel-element-operating temperature and a rather larger core with an increased number of fuel channels may well be practicable.

The Calder Hall station, comprising two reactors, is expected to cost about £16½ million. Its electrical output has been officially stated to

* Abstract. British Nuclear Energy Conference. Inaugural Meeting, London, November 30, 1955.
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‡ "A Programme of Nuclear Power," February, 1955, Cmd. 9389. (London: H.M. Stationery Office.)

be more than 50MW. Although it is too early to say with certainty, it is hoped that the early stations, each with two reactors, will have an output capacity of nearly 200MW sent out.

It is confidently thought that the design which will be developed in the coming months for the first Central Electricity Authority (C.E.A.) stations will enable the construction cost to be greatly reduced, perhaps to £150 or less per kilowatt. In addition to construction costs, the first charge of fuel elements, costing, in the case of a gas-cooled, graphite-moderated reactor, £25 or more per kilowatt, is most conveniently considered as part of the initial capital investment. This will attract interest charges only, since the cost of fuel replacement is an operating item. An optimistic estimate of construction costs of £125 per kilowatt for a station of 200MW s.o. plus £25 per kilowatt for uranium gives a total capital investment of £150 per kilowatt. There is, of course, insufficient experience yet from which to decide with confidence the amortisation period of a nuclear power station, but there is no compelling reason to believe that it should be less than twenty years. On the assumption of a 4 per cent annuity basis in calculating the annual charge on the construction cost and 4 per cent interest on the cost of the first charge of fuel, a total annual capital charge of 0·372d. per kilowatt-hour is obtained for a station operating at 75 per cent load factor.

Operating Costs

U.K.A.E.A. experience suggests that the "other works costs," comprising salaries, wages, stores and routine repairs and maintenance, will amount to about 0·06d. per kilowatt-hour. This is higher than for a coal-fired station, but higher reactor heat ratings should soon reverse that situation.

The fuel-replacement cost will obviously depend to a great extent on how long a fuel element can be permitted to remain in the reactor, and the assessment of the net cost is complicated because some of the uranium 238 is converted during irradiation into the valuable fissile material plutonium. The length of time that a fuel element can remain in the reactor is a factor which can be reliably determined only from experience; this is not yet available. There is no scientific reason, however, why 3000 megawatt days (MWD) per tonne of fuel cannot be achieved. Metallurgical research into the behaviour of the fuel element is continuous and it is perhaps worth pointing out that even if the first charge of the first reactor does not come up to expectations, the fruits of experience and research can be built into the replacement elements.

If 3000MWD per tonne is assumed to be achieved at the outset and 25 per cent of the reactor heat output to appear as net electrical output, the cost of replacement fuel is 0·266d. per kilowatt-hour. This, when added to the capital charges and the "other works costs," gives a gross generation cost of 0·698d. per kilowatt-hour. If a less optimistic estimate is made, e.g. a station of 170MW s.o. capacity costing £150 per kilowatt to construct and achieving only 2000MWD per tonne irradiation, a figure of 0·917d. per kilowatt-hour is obtained as the gross generation cost. In Table III these figures are compared with figures typical of the most advanced coal-fired plant planned up to 1962.

Columns (1) and (2) show the nuclear costs for the two cases considered. Column (3) shows figures typical of coal-fired 200MW units over the country as a whole and column (4) shows those for 200MW units scheduled to operate at 75 per cent load factor. It should be remembered that the latter are all coalfield stations and that their low generation cost is in part due to their geographical location. With the nuclear plant, the cost of generation is independent of the geographical location.

The importance of irradiation time is amply demonstrated by the annual fuel cost of columns (1) and (2), and it is probably true to say that the economic success of the reactor programme depends in no small measure upon the satisfactory solution of the fuel-element design problems.

As previously mentioned, these early reactors will produce plutonium, which will be extracted and processed by the U.K.A.E.A. for future use. Clearly some credit allowance should be made for this fuel, but it is difficult to assess what the credit should be, if it is borne in mind that it should be the average value of plutonium during the life of the reactor, and that any credit given will be a charge on the reactors which subsequently use the plutonium. The upper limit must clearly be the cost of obtaining an equivalent amount of uranium 235 separated by diffusion. U.K.A.E.A. experience shows that processed plutonium at £12,000 per kilogramme would be cheaper than uranium 235 from a diffusion plant. The lower limit must be defined by considering plutonium in association with depleted natural uranium, as an alternative to a fresh feed of natural uranium, but this is difficult to compute.

Apart from its use by the U.K.A.E.A. in prototypes of more advanced reactors, the use to which plutonium is most likely to be put in the early stages of a power programme is the enrichment of the uranium charge in the improved versions of the thermal reactor. It had been estimated by the U.K.A.E.A. that the improvements prescribed in reactor design when such enrichments become available are such that it would be economical to pay as much as £12,000 per kilogramme for plutonium. Even after allowing for the cost of extracting and possessing the plutonium at, say, £2000 per kilogramme, the net annual credit accruing to the early stations on this basis is just equal to the annual cost of replacement cartridges for 3000MWD irradiation. Table IV compares the net costs of electricity generation at nuclear and coal-fired stations.

If, as is likely, the figures for costs from the first nuclear station are somewhere between the two examples considered here, the net costs of generation should be very similar to those of the most up-to-date coal-fired plant.

The price of plutonium will probably remain fairly high until sometime during the 1970s, as the demand for pure fissile material is likely to keep pace with the increasing supplies during the next fifteen years or so.

Even if the price of plutonium does fall more than expected, or earlier than expected, that does not mean that the early designs of reactors, which have been justified on the basis of a reasonably good price for plutonium, will immediately become white elephants. There would still be the possibility of recycling the plutonium in the reactor which produced it, thus reducing the amount of natural uranium required. The exact way in which the plutonium would be fed to the reactor is uncertain. It could be blended with the depleted uranium feed but this would mean that the fabrication of a large quantity of metal from that stage on would have to be carried under alpha-active conditions. Alternatively, plutonium could be mixed with some low neutron-absorbing diluent and introduced as separate elements, but the rate of heat production in these elements would fall off rather rapidly. For technical reasons, the costs of recycling are difficult to compute at present, but the U.K.A.E.A have endeavoured to make an assessment and the results are reassuring.

More advanced types of reactor will eventually supersede the gas-cooled type, but while the prototypes are being proved, improvements will be made to the gas-cooled type, and it may be many years before it is superseded. Improvements in heat-transfer surfaces, metallurgical developments permitting higher temperatures, and possibly the use of a different coolant gas may, together, lead to great advances in heat rating and overall efficiency.

Table III—*Comparison of Costs of Nuclear and Coal-Fired Plant*

	(1) Nuclear station of 200MW s.o., 3000MWD/tonne	(2) Nuclear station of 170MW s.o., 2000MWD/tonne	(3) Coal-fired base-load plant	(4) Coal-fired base-load plant on coalfields
Load factor	75%	75%	69% average	75%
	£/kW s.o.	£/kW s.o.	£/kW s.o.	£/kW s.o.
Construction cost	125	150	54·3	54·3
Cost of initial charge of fuel	25	30	—	—
Total capital cost	150	180	54·3	54·3
	d/unit s.o.	d/unit s.o.	d/unit s.o.	d/unit s.o.
Annual charges on construction cost	0·336	0·403	0·129	0·119
Annual interest on initial charge of fuel	0·036	0·044	—	—
Other works costs	0·06	0·07	0·052	0·049
Annual fuel cost	0·266	0·4	0·375	0·351
Gross generation	0·698	0·917	0·556	0·519

* MWD = Megawatt days

Table IV—*Comparison of Net Generation Costs of Nuclear and Coal-Fired Plant*

	(1) Nuclear station of 200MW s.o., 3000MWD/tonne	(2) Nuclear station of 170MW s.o., 2000MWD/tonne	(3) Coal-fired base-load plant	(4) Coal-fired base-load plant on coalfields
Load factor	75%	75%	69% average	75%
	d/unit s.o.	d/unit s.o.	d/unit s.o.	d/unit s.o.
Gross generation cost	0·698	0·917	0·556	0·519
Credit for plutonium at £10,000 per kilogramme	0·266	0·266	—	—
Net generation cost	0·432	0·651	0·556	0·519

Proposed "Victoria Line" of London Transport

In the course of an address to the Metropolitan Section of the Institute of Transport on Monday last, Sir John Elliot, the chairman of London Transport, said that the proposed Route "C" tube railway from Victoria to Walthamstow would be called the "Victoria Line." The British Transport Commission, he said, was not at present committed to the construction of the line—although a Parliamentary Bill authorising it was about to become law—because it was a project of great size, and discussions as to its financing were still in progress. Sir John then went on to describe the improvements in travelling conditions and the time which would be saved by the introduction of the line. In addition to reducing traffic congestion by encouraging motorists to use quicker and cheaper tube facilities the line would also make possible certain reductions in London Transport's own road services. The line would be expensive to construct and alone could not pay its way. The annual interest charges on the construction costs of £50,000,000 might be well over £2,000,000; against this the net traffic receipts after deducting the running costs would be about £350,000. The line would, said Sir John, involve London Transport in an annual loss of about £2,250,000. Although Sir John was himself firmly against transport subsidies he thought that it might be decided an exception should be made of the Victoria Line and its cost be borne out of public funds because of the special and unprecedented problem of London's road congestion. He concluded by saying that it was certain no progress could be made in constructing the line until the basis of financing it had been settled.

Civil Engineering Work in Coal Mining

By H. R. KING.*

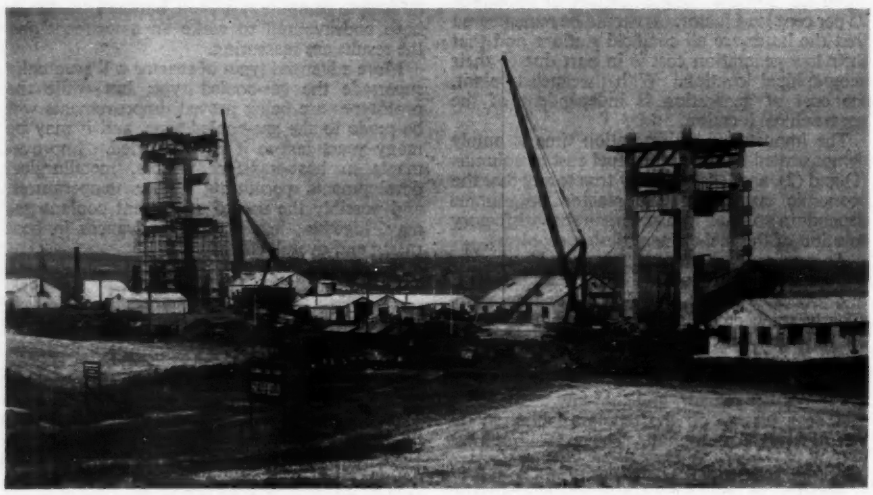
We reproduce hereunder abstracts from a lecture given to the Glasgow and West of Scotland Association of the Institution of Civil Engineers on November 11th. The National Coal Board's development programme for Scottish mines is briefly described, and some of its special problems are commented upon. The civil engineering aspects of various development schemes are then discussed.

IT can be truthfully stated that the general public does not appreciate the magnitude of the task on which the National Coal Board is engaged in reorganising and developing the coal mining industry in Great Britain. The speed in construction of a vast project such as a large new oil refinery makes a ready appeal to the imagination. Again, the size and extent of a hydro-electric scheme can be appreciated generally by the layman, and the massive concrete structures of the dam and power station strongly impress the viewer. In mining, much of the work is carried out underground and what the eye does not see tends to be forgotten. Further, the coal-fields are so scattered that it is much more difficult for those outside the National Coal Board to appreciate the sum total of what is now being done to modernise the industry and to meet the increasing demand for fuel.

It may be of interest to examine briefly some of the historical facts concerning the industry. About the middle of the nineteenth century coal production in Scotland was some 7,500,000 tons from 367 collieries and within ten years this figure had jumped to 12,500,000 tons from 497 collieries. The year of peak production in Scotland was 1913, when no less than 42,500,000 tons of coal were raised. Approximately 58 per cent of this large production came from the Central Coalfield, 22 per cent from Fife and Clackmannan, 11 per cent from Ayr and Dumfries, and 9 per cent from Mid and East Lothian. A decline then set in. In 1931 Scottish output at about 31,500,000 tons was some 25 per cent below the 1913 peak, and output from the Central Coalfield was lower by the very large margin of some 10,000,000 tons, or about 43 per cent. The Central Coalfield had passed its zenith. In the ten years prior to the outbreak of war in 1939 coal production was slightly in excess of 30,000,000 tons per annum, with a manpower varying between 87,000 and 95,000. A gradual fall in production took place during the war years, coupled with a declining manpower. In 1946, the year before nationalisation, 22·6 million tons of coal were produced, the total manpower being approximately 76,000 men.

When the industry came into public ownership on January 1, 1947, the National Coal Board took over 275 collieries in Scotland, which had been owned by some 120 separate companies. The Board operated 196 of these collieries and granted licences to continue private mining operations at the remaining seventy-nine small mines. Production from the seventy-nine licensed mines at 655,000 tons in 1947, falling to some 300,000 tons from fifty-three mines in 1955, has contributed usefully to Scottish output.

The serious drop in output from 1939 to 1947 was due to a steadily falling manpower and to other difficulties hampering development brought on by World War II. It was known that the Central Coalfield was gradually becoming exhausted and that many collieries elsewhere were nearing the end of their useful lives, but the full extent of the problem was not immediately apparent. Demand was rising sharply and, at the same time, manpower was rapidly declining. For at least fifteen years up to 1947 little new development to provide additional capacity had been carried out in Scotland and the National Coal Board was faced with a most urgent problem of development at a time when its immediate concern was a shortage of coal, which resulted in a fuel crisis. The first task of the Board was to set up a new organisation to take over from the previous owners. Continuity of management had to be assured so that the day-to-day operation of the collieries could proceed without interruption. As a result of a strenuous recruitment campaign, manpower in the industry increased rapidly and it was expected that a substantial rise in output would follow. Not until the initial organisational difficulties had been overcome was there full realisation of the extent to which additional productive capacity was required in Scotland. It was disturbing to see that not for many years could Scotland hope to re-establish itself in the export market at a satisfactory level. Steps had to be taken quickly to safeguard the short-term position and plans had to be prepared urgently to secure the future. The task was urgent and of extreme difficulty, faced as the Board was with a new organisation and a technical staff limited in numbers and lacking experience of new development work. Unified ownership did, however, make possible a co-ordinated development plan for the country as a whole, which was impossible when the ownership of the industry was in many hands.



Precast post-stressed concrete towers under construction at Seafield. These structures are used in the initial stages for supporting the shaft sinking winder pulleys and scaffold pulleys, and in the final stages for supporting the permanent winding engine house

Coal mining is an extractive industry and there is a steady exhaustion of productive capacity, which has been estimated at 4,000,000 to 5,000,000 tons per annum over Great Britain. Before any increase in output can be obtained this annual loss has to be made good by new development which must thus be a continuous process. Scotland is one of the older coalfields and at the end of the war the developed reserves were approaching exhaustion at a much faster rate than was general over the rest of Great Britain. Annual output in Scotland of 22·5 million tons in 1947 would have fallen to 16,000,000 tons in 1965 if the development of new collieries had not been undertaken. At most of the working collieries the best and most productive seams had been more fully exploited than had the poorer and thinner seams, with the result that the deterioration in quality and the increase in cost of production was progressive and rapid. Not only had an attempt to be made to maintain output, quality and efficiency by opening up new reserves, but the national demand made it necessary to increase annual output in Scotland as quickly as possible to around 30,000,000 tons per annum.

Unworked Reserves of Coal

Following the acquisition of coal royalties by the nation, it was estimated that the coal reserves in Scotland in 1942 amounted to 9622·3 million tons. Many of these reserves are not completely proved, but the figures do suggest a possible life of over 300 years for coal mining in Scotland. A more useful appreciation of the position may be obtained by considering the reserves which it was thought in 1942 would be developed and worked in a period of some eighty years. Based on data concerning these reserves available in 1942, the estimated quantities of the various types of coal were as follows :—

Type	Millions of tons
Anthracite and semi-anthracite	84
Coals of medium volatile matter (non-coking)	150
Carbonisation coals (coke ovens)...	288
Carbonisation coals (gas works)	400
Domestic, industrial, &c.	1444
Total	2366

It will be noted that reserves of carbonisation coals suitable for coke ovens or gas works total 688 million tons, which equals about 29 per cent of the total. Unfortunately, the remaining unexploited reserves lie at considerable depth or far out to sea under the Firth of Forth. New collieries are therefore very costly and are necessarily long-term projects. In normal circumstances a new pit to produce 1,000,000 tons per annum will cost from £7,000,000 to £10,000,000 and will take about ten years to sink, equip and develop. In Scotland fifteen new sinkings are required to produce some 14,000,000 tons per annum by 1965. In addition, many of the continuing collieries are being modernised so that they and others may produce the balance of 16,000,000 tons required to raise Scottish output to 30,000,000 tons per annum.

The Programme of Reconstruction

In the Board's "Plan for Coal," published in 1949, an annual production of some 240 million tons is aimed at in the period 1961–65 for Great Britain, and Scotland's share is estimated at around 30,000,000 tons. Production in Scotland in 1949 was 23·8 million tons, so that the increase envisaged is one of some 28 per cent. Productivity, as measured by overall output per man-shift (O.M.S.), is estimated to increase from 22·4 cwt in 1949 to about 30 cwt in 1965, or about 35 per cent. The corresponding increases in output and O.M.S. for Great Britain as a whole are 18 per cent and 34 per cent.

Scotland's task is a heavy one. The programme includes fifteen new sinkings, of which five are on the sites of existing pits, sixty new or reconstructed surface drift mines and thirty-seven major reconstructions, some of which involve shaft deepenings. The total cost of the reconstruction may well exceed £100 million if wages and materials costs continue to rise as

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they have done since 1947. The fast rate of exhaustion of existing Scottish pits is a factor of high importance in planning ahead. In the eight years to January 1, 1955, sixty-seven collieries were closed, involving the loss of an annual tonnage of some 1·86 millions.

Three phases of development were planned for the technical reorganisation and reconstruction of the industry. The first of these was the immediate task of developing additional face room to replace wastage and to maintain and, if possible, increase production. For many years much shallow coal had been won by surface drift mines. A quick review was made of the different coalfields and a large number of areas of coal were selected which appeared to be capable of yielding outputs of 100 to 500 tons per day for periods of five to twenty years. Using new techniques, it was found that these drift mines could generally be developed to full production in about two years from the start of work on the site, compared with a ten-year period for a new deep sinking. The main feature of the new drift mines is a simplified surface layout, which requires few men, and a much improved underground transport system, in which direct rope and locomotive haulage with 2-ton capacity drop-bottom mine cars or all-conveyor layouts are frequently used. The efficiency of many of the small units has been outstanding and several have yielded an annual overall O.M.S. of 60 cwt to 70 cwt, or nearly three times the overall O.M.S. in Scotland. Altogether some sixty surface drift mines were planned, of which thirty-seven are now in production and eight are at varying stages of development. It was not intended that all sixty drift mines would be in production at one time, as several were reserved as replacements for short-life units. The output from the new surface drift mines was 1·8 million tons in 1954 and is expected to vary in the future between 2,500,000 and 3,500,000 tons per annum. It is of interest to note that the annual tonnage from new surface drift mines in 1954 is about equal to the cumulative annual total of 1·86 million tons lost through closures in the eight years to January 1, 1955. The setting away of drift mines can now be said to have become virtually a routine job and the major part of the construction work has been accomplished. Standardisation of surface and underground layout and equipment has done much to simplify the operation.

The second stage of reorganisation was the introduction of minor reconstruction schemes embodying improvements in underground transport, the introduction of labour-saving devices and of modifications on the surface to reduce manpower and increase efficiency. There is little doubt that of all underground operations, one which provides a great scope for improvement is transport. For many years transport in Scottish pits has been predominantly by some form of rope haulage, in numerous cases over undulating and tortuous roadways. Some of the blame for the steady fall in face O.M.S. must rest on a transport system which has too often failed to keep pace with improvements in face mechanisation. To provide level roadways for locomotive haulage is frequently a difficult task in old pits, but appreciable progress has been made. Considerable progress has been made in the use of automatic devices, and power loading is being rapidly extended at the coal face.

The third phase of reorganisation and, indeed, the key to the future success of the industry in Scotland lies in the successful completion of thirty-seven major reconstruction schemes and fifteen deep new sinkings. These together will produce about 70 per cent of the future output of some 30,000,000 tons. At both the major reconstructions and the new sinkings the most modern techniques are being applied.

The Use of Consultants

The reconstruction of the industry has considerably widened the scope of the civil engineer in mining. In the past the civil engineer's services were utilised for the most part in cases where difficult site conditions were encountered or where special foundations had to be provided. Few concrete structures were used for colliery buildings and steel-framed brick-filled buildings and steel head frames were the general rule. At the new collieries modern techniques in building and in design are widely applied and the use of concrete in place of steel is gaining favour.

For a new sinking, the Board now frequently engages a civil engineering consultant to deal with general civil engineering works and to be responsible for co-ordinating these in phase with mining development. In the initial stages such works would comprise the clearing and grading of the site, the provision of access roadways, drainage, sewage, &c., initial shaft and fan drift excavations to rockhead, construction of shaft collars and fan drifts, and construction of foundations for sinking headframes, winding engines, &c. In the later stages, the Board normally utilises its own building department for much of the design work and for the necessary architectural services, but the consultant is still called upon to help in dealing with such specialised works as piling and foundations, reinforced concrete structures and railway siding formations. In some instances, a firm of consulting civil engineers is engaged to design the surface layout in conjunction with the Board's staff and to undertake responsibility for the co-ordination of the whole of the surface works and equipment.

The Board also, from time to time, engages firms of designer/contractors when it is considered advantageous to do so, e.g. firms specialising in the construction of coal preparation plants. On the Continent it has been common practice for many years to place the entire work of design, manufacture and construction of a new colliery in the hands of a specialist engineering firm which itself manufactures most of the plant and equipment. There is no comparable service in this country, but, in certain instances, firms of designer/contractors have been engaged who are responsible, in conjunction with the Board's staff, for the complete design of the surface arrangements and shaft equipment at a new colliery. The designer/contractor acts as the main contractor and undertakes the construction and co-ordination of most of the work on the site on the basis of a selected contract. Certain items such as winding engines and power supply, &c., are, of course, arranged by the Board's staff and are excluded from the contract. Whatever procedure is adopted there is a considerable amount of civil engineering work to be executed with a wide field for using the most up-to-date techniques.

Mention has already been made of the working of shallow deposits of coal by means of inclined drifts from the surface. Civil engineering contractors are frequently engaged by the Board to construct the mine portals and occasionally to drive the inclined tunnels in stone to the coal. These openings down to rockhead have sometimes to be driven through unconsolidated deposits and in such circumstances considerable ingenuity has to be exercised.

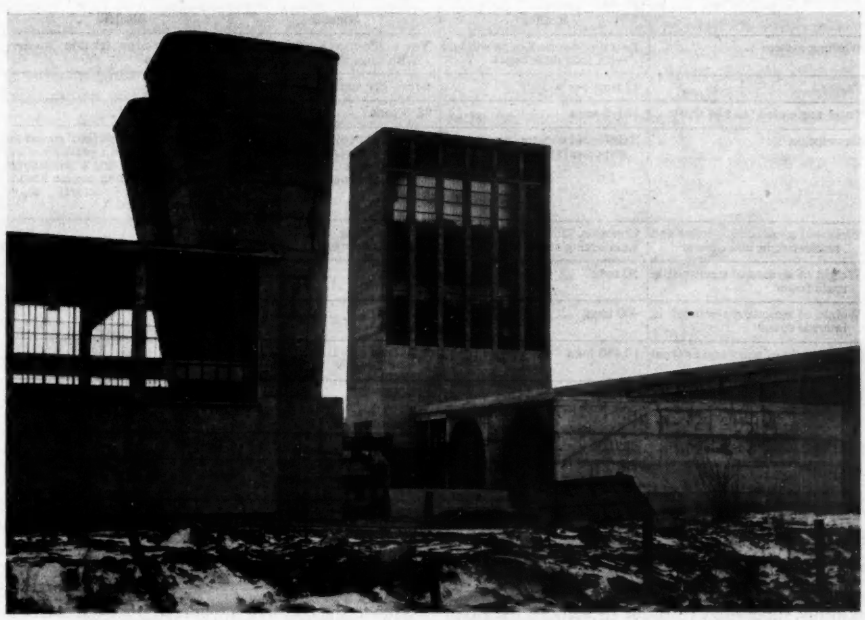
At one time shaft collars and fan drifts were designed and constructed by the shaft sinking contractor. To-day, it is common practice for a consultant civil engineer in conjunction with the responsible Board officials to design these items and to obtain competitive tenders for their construction. Modern winding techniques are such that shaft collars become more complex and have frequently to be tied in with the tower or headframe foundations.

Shaft Sinking

The Board's programme in Scotland involves the sinking of some 10 miles of concrete-lined shafts. These shafts are normally from 20ft to 24ft in diameter and may be sunk to depths of up to 3000ft. Considerable difficulties are often experienced in water-bearing strata and "silicatisation" and cementation have to be resorted to. Where there are deposits of alluvium or other unconsolidated matter near the surface, freezing may be required in the initial stages.

In normal strata the usual rate of sinking in this country is about 100ft per month. This is one job which should be mechanised and in which new techniques are required. Much can be learned from South Africa, where some of the new shafts at the Orange Free State gold mines have been sunk at phenomenal speed. Approximately fifty shafts have been put down over the past ten years providing considerable scope for the adoption of new techniques. The shafts, circular in shape, vary in diameter from 20ft to 25ft and are lined with concrete. In general, they have the advantage of being in strong ground which does not require temporary supports. During sinking operations it is thus possible to use multi-deck scaffolds so that sinking and walling can be carried on simultaneously. Cactus grabs were used for mucking in some of the shafts. Average weekly rates of over 100ft were common and on many occasions this was raised to 130ft to 140ft. The record advance was 597ft in one month in a 21ft diameter shaft with concreting carried out close to the excavation. More recently, a record monthly advance of 763ft has been claimed for the Monarch shaft of the West Rand Consolidated Mines.

The practice now favoured in South Africa is to erect permanent headgears before sinking commences and most of these are of reinforced concrete construction. Designs of headgear vary



Concrete structures at Rothes Colliery, Fifeshire. One of the two winder towers and the twin fan evassees may be seen. The illustration shows progress made early this year

from copies of the conventional steel type to square towers, or even round towers like lighthouses. One square tower 103ft high in post-stressed reinforced concrete for two ground-mounted winders was erected in nine days. Another square tower, 144ft high, in reinforced concrete was erected in seventeen days. Raisable shuttering has been developed which allows continuous pouring of concrete. Until recently, few civil engineering firms in this country appear to have been prepared to tackle this rather hazardous mining operation of sinking, although it is one of which most civil engineering contractors will probably have at least some experience.

Underground Tunnelling

The wide adoption of locomotive haulage underground has resulted in the driving of many miles of tunnel in stone, particularly at the new sinkings. In all, some 130 miles of tunnel have to be driven in connection with the Board's reconstruction programme. The Board is utilising the services of civil engineering contractors for some of this work, which requires to be highly mechanised, efficiently organised and skilfully supervised in order to achieve the high speeds of drive required.

Once work has started on the site of a new sinking, two factors which more than any other determine the completion date are shaft sinking and underground drives in stone to the coal. There have been excellent examples of high-speed execution and fast drives in other industries and in foreign countries. Much guidance can be obtained from an examination of some of these achievements. In tunnelling, spectacular progress has been made in a number of hydro-electric and drainage schemes. In coal mining in this country, the restrictions imposed by the statutory regulations in respect of safety and the use of explosives limit to some extent the speed of underground drives. Nevertheless, considerable improvement is possible and, indeed, essential, and there is no reason why advances of 100ft to 120ft per week—which is more than twice the advance normally achieved—should not be obtained regularly with suitable equipment and proper organisation. There are, of course, some examples of excellent progress in this country.

One large colliery in Germany which has specialised in underground drifting now accepts as a standard an advance of 120ft to 150ft per week in tunnels of large cross section. It is unlikely that the pulls of 10ft achieved at this colliery could be equalled in British conditions using permitted explosives, but a pull of 8ft should be possible. The two major facts which stand out in the German performance are (1) a continuous operation at the face by using four shifts per day of stone miners, and (2) an organisation such that a complete cycle of advance is made in under two shifts, or more than two complete cycles in twenty-four hours.

Winder Headframe Construction

The selection of the type of structure for winder headframes has been based, in many instances, more on personal preference than on factual data. At present prices, however, it is believed that a properly designed concrete structure of height 120ft can be built for some 70 per cent of the cost of a structural steel headframe designed for the same duty. Recently, firm prices were obtained for a conventional headframe in alternative structural steel and reinforced concrete designs. A clutched drum winder with double-deck cages winding from depths of 2160ft and 2640ft is to be used. The payload is 10 tons and the total suspended load in the shaft 70 tons. The lowest quotations obtained gave a price advantage of 29·5 per cent in favour of reinforced concrete.

Although the above price comparisons favour reinforced concrete construction, it is not possible to lay down a hard and fast rule. This is due to the fact that a tendered price depends on such items as the nature of the surface, labour conditions, the demand for steel and any special site conditions. Following a careful examination, it would appear, however, that the price for reinforced concrete would equal that of steel at heights approaching some 160ft to 170ft and at heights greater than 170ft to 180ft reinforced concrete would be dearer than steel.

Examples of Winder Tower Construction Costs

	Rothes	Kinneil	Seafield
Winding system	Two single-rope Koepe winders with four deck cages	Two single-rope Koepe winders with three deck cages	One multi-rope friction winder with skips
Payload	12 tons per winder	6 tons per winder	15 tons
Total suspended load in shaft	161·6 tons	98·7 tons	75·5 tons
Description	Reinforced concrete tower with structural steel internal tower	Structural steel tower with brick cladding, concrete floors and structural steel internal tower	Post-stressed reinforced concrete frame built with prefabricated blocks and having a reinforced concrete winding engine house on top. Structural steel internal tower
Weight of reinforced concrete and brickwork in main tower	Concrete, 9550 tons Reinforcing steel, 450 tons	Brick cladding, &c., 875 tons Concrete floors, 915 tons	4000 tons
Weight of structural steelwork in main tower	50 tons	640 tons	—
Weight of structural steelwork in internal tower	400 tons	370 tons	250 tons
Total weight of main and internal towers	10,450 tons	2800 tons	4250 tons
Cost of main tower structure	£95,000	£106,000	Post-stressed base, £28,000 Reinforced concrete winder house, £37,000
Cost of internal tower	£75,000	Included above	£30,000
Cost of concrete floors, brick cladding, glazing, &c.	£28,000	£44,000	—
Cost of foundations	£18,000 (weight 1500 tons)	£9000 (weight 900 tons)	£10,000
Total cost (approximately)	£216,000	£159,000	£105,000

A similar cost comparison for winder towers is not readily available, but it is possible to give data for three different types of tower (see table). As the winding duties and loadings are all different, the relative costs are not strictly comparable, but it is possible to draw certain broad conclusions. Rothes Colliery provides an example of an excellent engineering structure in reinforced concrete, as the illustration (page 831) shows, but the weight of materials used appears to be somewhat high. The tower, however, is not heavy in relation to similar structures in Holland. Kinneil Colliery tower, in structural steel, is relatively economic in the use of materials, but brick cladding is an expensive form of protection. Consideration was given to the use of cheaper forms of cladding, but these were not adopted because of possible deterioration through the action of the damp sea atmosphere. The use of multi-rope friction winders provides an opportunity for cheaper tower construction, whether in reinforced concrete or steel. At Seafield Colliery, the design of the winder tower is of particular interest. In the cases of Rothes and Kinneil, the towers were built round the sinking winders without interruption of sinking operations, whereas at Seafield an entirely different principle was adopted. The lower portion of the tower is of prefabricated post-stressed concrete design and is to be used as a sinking headframe. This part of the structure consists of four vertical columns with six horizontal bracing beams. Each column is of 5ft by 4ft cross section and is built up of 12in deep prefabricated concrete blocks which are clamped together in groups of seventeen, as construction proceeds, by high-tensile internal vertical ties. The horizontal beams are similarly constructed. When the bumper beam or floor of the winder house is reached each column is tied to its foundation by a series of highly tensioned steel cables which are threaded through preformed ducts in the prefabricated blocks. A frame, strong both in compression and in tension, is thus provided for sinking purposes. During sinking operations a reinforced concrete winder house will be built on top of the frame and the permanent winder will be installed. Work is shown in progress at Seafield in the illustration on page 830.

Other Surface Works

A certain amount of civil engineering work is involved in preparing the foundations for coal preparation plants, dirt bunkers, car circulation halls, winder towers, &c. Piling is sometimes necessary in soft ground. Many of the coal preparation plants, dirt bunkers, &c., are constructed in reinforced concrete and for such structures the Board normally engages consultants or designer/contractors.

Where large outputs have to be dealt with, extensive siding accommodation for wagons is necessary. In the earlier designs of large new collieries it was considered that the best arrangement was the provision of relatively flat sidings with locomotives for shunting, except on the portions of track through the preparation plant where the wagons would be power controlled. This method is not now thought to be highly efficient either in manpower requirements or in operational cost owing to the considerable amount of shunting and marshalling involved. More recently, attention has been directed to mechanical wagon handling equipment, and, at some of the new collieries, arrangements have been made to use wagon transporters on both empty and load sides of the preparation plant. On the empty side, the wagons are fed by gravity to a power-driven feeder and weighbridge and, after taring, are loaded individually to a transporter for distribution to the various loading tracks under the preparation plant. On leaving the transporter, the wagons come under positive control by means of power-operated "mules," or, alternatively, are fed by gravity to the loading and stopping points, where they are controlled by remotely operated brakes. A second transporter, incorporating a weighbridge, is provided on the load side to weigh the full wagons and marshal them into the proper load sidings. Considerable benefits accrue from this latter operation, as full trains can be built up for despatch to the railway without the need for extensive marshalling. A mechanical handling wagon installation, as described, may cost as much as £40,000 for a large colliery, but against this must be set a saving in operational manpower of up to 50 per cent, a reduction in the total length of sidings provided, a reduced number of crossings and turnouts, and an economy in space. Experiments are at present continuing in the use of trains of 24½-ton wagons between selected collieries and large consumers. It is anticipated that the use of large-capacity wagons will be extended in the future. The formation work is normally carried out by civil engineering firms, including excavation, levelling, grading, drainage, construction of culverts, &c. The Board engages specialist firms for the track work.

It has already been indicated that the cost of a large modern colliery may be from £7,000,000 to £10,000,000. The surface works alone may cost £2,500,000 to £3,000,000, of which about half will be civil engineering and building work and half plant and equipment. The making of the shafts may cost £750,000, excluding the shaft equipment, and pit bottom drivages and tunnels in stone may cost between £2,000,000 and £3,000,000. These figures give some indication of the extent to which civil engineering services might be utilised.

Canada's First Steamboat

By H. PHILIP SPRATT

Three years before Henry Bell, with his "Comet" of 1812, introduced the first public steamboat service in Europe, a more powerful and commodious "smoke launch" had already been constructed in Canada, complete with her boiler, machinery and paddle-wheels.

THE first Canadian steamboat was the P.S. "Accommodation" of 1809, built at Montreal[1] by the brewer John Molson (1763–1836), a native of Lincolnshire,[2] and his two British partners, John Bruce (shipbuilder) and Captain John Jackson.[3] The keel was laid on March 27th; the vessel was launched on August 19, 1809, and completed two months later, for service on the River St. Lawrence.

Of her wooden hull construction, very little precise detail is now available. Molson is known to have had information of the steamboat "Clermont" (1807), which Robert Fulton had put into service on the River Hudson at New York two years earlier, and to have been inspired by the American enterprise. On the other hand, his partners Bruce and Jackson would doubtless have imparted some of their British influence to the plans. The "Accommodation" was fitted with berths for twenty passengers. She carried a mast, from which a sail could be spread "when the wind is favourable, which will occasionally accelerate her headway." The total crew consisted of six men.

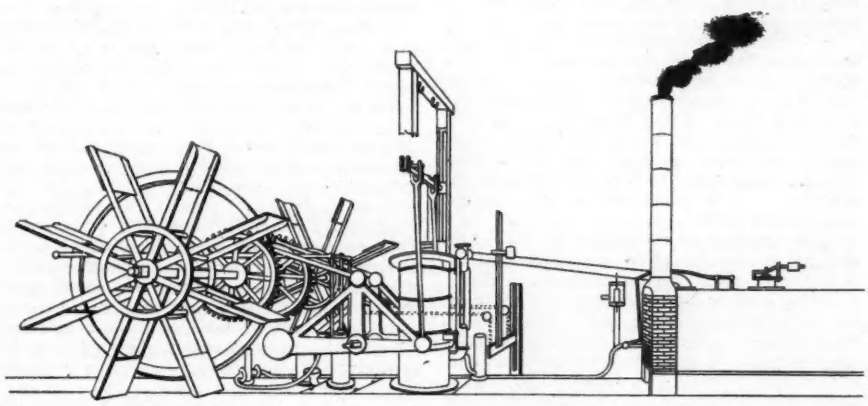
The machinery of the "Accommodation" is said to have been rated at 6 nominal h.p. The vertical steam cylinder, about 16in diameter by 3ft stroke, and the piston were of cast iron and turned at the Forges de Saint-Maurice,[4] at Three Rivers. This indicates the standard of technical competence available in Canada at the time.[5] No detailed specification has been preserved, but we read[6] that: "The steamboat receives her impulse from an open, double-spoked perpendicular wheel on each side, without any circular band or rim. To the end of each double spoke is fixed a square board, which enters the water, and by the rotary motion of the wheel acts like a paddle. The wheels are put and kept in motion by steam within the vessel."

From comparison with the "Clermont" machinery (shown in the illustration), which Molson undoubtedly had in mind, it would seem that the vertical piston drove the paddle shaft by means of return connecting-rods and bell-crank side levers. The smaller parts of machinery were made by Messrs. Geo. Platt and Ezekiel Cutter, at Montreal.[7] Steam at 2 lb per square inch pressure above the atmospheric was supplied from an iron boiler, which was fired with coal. The steam was, of course, exhausted into a condenser. It is probable that the paddle wheels were about 12ft diameter, with radial float boards 2·5ft long and 2ft wide. Such wheels would have made about 15 r.p.m. for a speed of 4·5 m.p.h.

The steam cylinder was fitted aboard on October 9th, and some trials were run on the St. Lawrence, down to Boucherville Island and back, later in the month. The "Accommodation" left Montreal for her maiden trip, under the command of Captain John Jackson, and with the French-Canadian river pilot Amable Laviolette, on November 1, 1809. She arrived at Quebec on Saturday, November 4th, in sixty-six hours, of which time thirty hours were spent at anchor. The distance of 160 statute miles was thus covered at a mean speed of 4·45 m.p.h. The local report[8] commented: "It is obvious that her machinery, at present, has not sufficient force for this river." In the French version of this report, the vessel was described as "*la chaloupe à fumée*," or smoke launch.

The "Accommodation" left Montreal for her second round trip on November 15th. At the end of her first season the crew were paid off on January 12, 1810, and the vessel was laid up for the winter near Sorel, on the River Richelieu. At this point John Jackson withdrew (or was dismissed) from the partnership, and another mechanician, James Clark, was recruited in his stead. Molson stove to improve the machinery, and a more powerful boiler was fitted.

Thus reconditioned, the "Accommodation" commenced her second season in June, 1810, as advertised,[9] under Captain John Bruce and her former pilot, Amable Laviolette, and ran for more than four months. Meanwhile, in the summer, Molson had made a hurried visit to New York to consult with Robert Fulton. As the result, Fulton offered to prepare plans for a steamboat to run at 5 m.p.h. in still water,[10] but this offer does not seem to have been accepted. The "Accommodation" never became a commercial success, but the construction of her machinery in Canada, three years before the "Comet" in Scotland, was certainly a notable technical achievement.



Machinery of Fulton's "Clermont" (1807), which inspired Canada's first steamboat

In the summer of 1812 Molson launched[11] his second steamboat, the "Swiftsure," from the yards of Messrs. Logan and Co., near his brewery in Monarque Street, Montreal. This more ambitious vessel measured 140ft on deck,[12] 130ft on keel, and 24ft beam; she was fitted with thirty berths, and her machinery of 26 nominal h.p. was purchased from Messrs. Boulton, Watt and Co. The steam cylinder was 28in diameter by 4ft stroke,[13] and the boiler pressure was said to have been 4 lb per square inch; the total crew consisted of thirteen men.

The "Swiftsure" ran her trials in November, 1812. She entered service on the St. Lawrence in 1813, and made her first scheduled arrival at Quebec on May 2nd.[14] The normal speed of the vessel was 7 m.p.h. She was chartered to the British Government in 1813 for the transport of troops and stores, and remained in service until 1818. Her timbers had then become rotten; the hull was condemned, but her machinery was transferred into the "New Swiftsure."

The third Molson steamboat was the "Malsham" of 1815, fitted with side-lever machinery of 45 nominal h.p., also from Messrs. Boulton, Watt and Co.; the steam cylinder was 36in diameter by 4ft stroke. Competition soon came from the "Car of Commerce" in 1816, built for Thomas Torrance on the lines of the Fulton steamboat "Car of Neptune" (1809). Molson replied with the "Lady Sherbrooke," launched on May 16, 1817, from the yards of Messrs. Logan and Co., at Montreal. She measured 170ft on deck and 30ft beam, and was fitted with side-lever machinery of 60 nominal h.p. from Messrs. Boulton, Watt and Co. The steam cylinder was 42in diameter by 4ft stroke.

Two other steamboats, the "Quebec" and the "Caledonia," of 45 nominal h.p., followed soon after in 1817. The machinery for the "Quebec" of 500 tons was obtained from Messrs. Maudslay, Sons and Field, of London; it was rated at 56 nominal h.p. and developed 100 indicated h.p.[15] In 1819, within a decade of the pioneer "Accommodation" venture, the St. Lawrence had a reliable, almost daily steamer service.[16]

Principal dimensions of the "Accommodation" were as follows:—Burden, about 85 tons; length on deck, 85ft; length of keel, 75ft; breadth of hull, about 15ft; breadth over paddle wheels, about 21ft; depth, 7ft; draught, about 2·5ft.

I wish to record my sincere thanks for the invaluable help received from Miss K. T. Trenholme, of McGill University Library in Montreal; from Mr. J. C. Bonenfant, Librarian at Quebec; from Mr. Louis Carrier, Curator of the Château de Ramezay; and, above all, from Mr. Merrill Denison, of New York.

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Full-Scale Tests on Concrete-Encased Steel Stanchions

By Dr. OSCAR FABER

Abstracts are printed here from a paper entitled "Savings to be Effected by the More Rational Design of Cased Stanchions as a Result of Recent Full-Size Tests," delivered before a joint meeting of the British Constructional Steelwork Association and the Institution of Structural Engineers on November 29th. A design method for a steel stanchion encased in concrete is elaborated, in which the load bearing capabilities of the concrete are taken into account.

IT has long been appreciated that the strength of stanchions can be increased if they are cased in concrete. In B.S. 449 : 1948, it is provided in Clause 18(*b*)

"CASED STRUTS. Struts may be designed as cased struts when the following conditions are fulfilled :—

"(i) The section is of single web and I-form.

"(ii) The steel strut is unpainted and solidly encased in ordinary dense concrete consisting of a 1 : 2 : 4 or richer mix.

"(iii) The minimum width of solid casing is equal to $b+4$in, where b is the width of the steel flange in inches.

"(iv) The surface and edges of the steel strut have a concrete cover of not less than 2in.

"(v) The casing is effectively reinforced with wire to B.S. 785, 'Rolled Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement.' The wire shall be at least $\frac{1}{16}$in diameter and the reinforcement shall be in the form of stirrups or binding at not more than 6in pitch, and so arranged as to pass through the centre of the covering of the edges and outer faces of the flanges.

"In selecting the permissible axial stress on the steel section (which shall be deemed to carry the whole load), the radius of gyration r about the weak axis of I-shapes (single web) not exceeding 30in deep (over plating where used) may be taken as $0{\cdot}2\,(b+4)$ in. In no case shall this value exceed the stress permitted on the uncased section by more than 50 per cent, nor shall the effective ratio of slenderness of the uncased section exceed 250.

"The radius of gyration about the other axis shall be taken as that of the uncased section."

It is to be noted that the minimum thickness of casing is to be 2in. The load still has to be considered as carried solely on the stanchion and the only advantage obtained from the casing is that the radius of gyration about the weak axis may be taken as $0{\cdot}2\,(b+4)$, where b is the breadth of the joist.

It will be seen from the wording of the clause that even when the thickness of the casing is more than 2in, only the value of 2in may be taken into account and then only in increasing the radius of gyration for determining the buckling factor. Thus, for example, on a 10in+6in joist cased with 2in all round it then becomes 10in wide across the casing, the minimum radius of gyration may be taken as

$$0{\cdot}2\times 10\text{in}=2\text{in}.$$

Whereas without the casing the minimum radius of gyration is 1·36in and it will be seen, therefore, that the advantage to be obtained in this code is limited to the advantage that can be obtained by increasing the minimum radius of gyration by approximately 50 per cent, which means, of course, that in long sections it might be appreciable, but in short sections negligible.

The advantage of this concession is, however, still further reduced by the requirement that the stress on the uncased section shall not be increased by more than 50 per cent nor shall the effective ratio of slenderness of the uncased section exceed 250.

In the draft of the 1955 edition of B.S. 449 it was evidently felt that some greater allowance could be made and the revised provisions are as follows :—

"CASED STRUTS. Struts of single British Standard I beams to B.S. 4A, or British Standard channels back-to-back, of symmetrical I form, may be designed as cased struts when the following conditions are fulfilled :—

"(i) The steel strut is unpainted and solidly encased in ordinary dense concrete with an aggregate not exceeding $\frac{3}{4}$in and of a works strength not less than 3500 lb per square inch at twenty-eight days when tested in accordance with B.S. 1881, 'Methods for Testing Concrete,' Part 6, 'Making and Curing Compression Test Cubes in the Laboratory,' and Part 8, 'Test for Compressive Strength of Moulded Cubes.'

"(ii) The minimum width of solid casing is equal to $b+4$in, where b is the width of the steel flange in inches.

"(iii) The surface and edges of the steel strut have a concrete cover of not less than 2in.

"(iv) The casing is effectively reinforced with wire to B.S. 785, 'Rolled Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement.' The wire shall be at least $\frac{1}{16}$in diameter and the reinforcement shall be in the form of stirrups or binding at not more than 6in pitch, so arranged as to pass through the centre of the covering of the edges and outer faces of the flanges and supported by longitudinal spacing bars not less than four in number.

"The radius of gyration r of the strut section about the axis in the plane of its web may be taken as $0{\cdot}2\,(b+4)$ in. The radius of gyration about its other axis shall be taken as that of the uncased section.

"In computing the axial load carried by the cased strut, the concrete, measured as a rectangular section of mean depth between the flanges of the steel section and width equal to the width of the flanges, shall be taken as assisting in carrying the load, using a modular ratio of 15.

"The permissible axial load on a cased strut shall not exceed 1·5 times that which would be permitted on the uncased section, nor shall the ratio of slenderness of the uncased section, measured over its full length centre to centre of connections, exceed 250.

"These approximate methods of calculation shall not be applied to struts having an overall section greater than 30in×18in, the dimension of 30in being measured parallel to the web."

The provision resembles that of the 1948 Code in limiting the value of the solid casing to 2in so that the overall width of the stanchion shall be taken at $b+4$ and the radius of gyration has still to be taken as

$$r=0{\cdot}2(b+4)$$

The new feature is that the concrete measured as a rectangular section of mean depth between the flanges of the steel section and width equal to the width of the flanges shall be taken as assisting in carrying the load using a modular ratio of 15. In other words, the small area of concrete contained inside the flanges may be taken into account as load bearing. This permission is, however, as before, reduced by the ruling that the permissible load shall not exceed 1·5 times that which would be permitted on the uncased section, nor shall the ratio of slenderness of the uncased section exceed 250. Nevertheless, it does on occasions give considerably greater allowance to the casing than do the provisions of the 1948 Code.

The author was of the opinion that both these Codes give inadequate allowance for increased strength of concrete casings under certain circumstances, and he was in particular of the opinion that the concrete casing may have very considerable load bearing value even when the thickness of the casing greatly exceeds the 2in which alone is allowed to be taken into account in the two editions of B.S. 449 as at present drafted.

As an example Table I gives details out of some stanchions which were tested to destruction full scale. There are eighteen stanchions here to choose from, but if we consider the one marked C.6 this has the following properties. The casing is 20in square, containing a 12in by 8in joist and the length of the stanchion is 18ft. The permissible load based on B.S. 449 : 1948, taking the effective length of the stanchion as 0·85 of the actual length of 18ft, comes to 101 tons.

The permissible load calculated in the same way in accordance with the new draft 1955 comes to 120 tons (being, in fact, limited by the rule that it must not exceed by more than 50 per cent the permissible load on the plain joist) and the permissible load on a new basis proposed by the author and to be described in greater detail in a moment comes to 232 tons. The full-scale test load on the specimen was 647 tons. From this it would seem that the new basis has an ample margin to justify it.

The method of calculation advocated is as follows :—

(*a*) Calculate $(18000\ A_S+760A_C$ lb), where A_S is the total area of steel plus vertical reinforcements, and A_C is the total area of concrete in square inches.

(*b*) Calculate the slenderness ratio, accurately as a composite section taking $m=15$; alternatively, as an approximation, taking r as $0{\cdot}2\times$least width of casing. Note : this approximation gives r lower than the true value. Thus, in specimen C6, the true value works out at 4·8in, while $0{\cdot}2\text{in}\times$least width equals 4·0in. In the calculations in this paper the approximate value has been used.

(*c*) Calculate the safe stress in tons per square inch from Robertson's formula in B.S. 449:1955

TABLE I—*Calculated and Test Loads*

Member	Overall size	Length L	Permissible loads			Ultimate load from tests	Factor of safety or load factor on basis of new design method
			Based on B.S. 449/1948	Based on B.S. 449/1955 draft	New basis of design		
		Ft	Tons	Tons	Tons	Tons	
A1	10in×6in I uncased	12	54	54	54	155	2·87
A2	14in×10in (10in×6in I)	12	71	81	92	250	2·72
A3	24in×12in (10in×6in I)	12	71	81	147	450	3·06
A4	26in×14in (10in×6in I)	12	71	81	183	615	3·36
A5	28in×15in (10in×6in I)	12	71	81	211	670	3·17
A6	20in×20in (10in×6in I)	12	71	81	211	555	2·63
B1	12in×8in I uncased	12	111	111	111	273	2·46
B2	16in×12in (12in×8in I)	12	125	160	153	430	2·81
B3	24in×12in (12in×8in I)	12	125	160	187	420	2·25
B4	26in×14in (12in×8in I)	12	125	160	226	676	2·99
B5	28in×15in (12in×8in I)	12	125	160	254	870	3·43
B6	20in×20in (12in×8in I)	12	125	160	257	870	3·38
C1	12in×8in I uncased	18	80	80	80	235	2·94
C2	16in×12in (12in×8in I)	18	101	120	124	426	3·44
C3	24in×12in (12in×8in I)	18	101	120	152	568	3·74
C4	26in×14in (12in×8in I)	18	101	120	192	609	3·17
C5	28in×15in (12in×8in I)	18	101	120	218	790	3·62
C6	20in×20in (12in×8in I)	18	101	120	232	647	2·79
Preliminary A4	36in×15in (10in×6in I)	12	71	81	235	748	3·19

draft, Table 14 (or in B.S. 449 : 1948, Table 7), and reduce the safe load on the stanchion in the ratio that this figure bears to 9 tons per square inch (the safe stress with no slenderness).

This sounds more complicated than it is. Perhaps an example of the calculation that gave 232 tons for test member C6 would make it easier. We have :

Area of 12in × 8in	19·12 sq in
Area of small vertical reinforcements to hold the binding	3·52 sq in
Total area of steel	22·64 sq in
Load on steel at 18,000 lb/sq in ...	= 182 tons
Area of concrete	= 400 − 22·64 sq in of steel
	= 377 sq in
Load on concrete at 760 lb/sq in ...	= 128 tons
Maximum load before slenderness reduction ... ... 182 + 128	= 310 tons
Slenderness ratio ... ... l/r	$= \frac{0{\cdot}85 \times 216\text{in}}{0{\cdot}2 \times 20\text{in}}$
	= 46

Safe stress from B.S. 449 : 1948, Table 7, corresponding to this slenderness ratio is 6·77 tons per square inch.

Reduction factor	$= \frac{6{\cdot}77}{9}$
	= 0·75
Permissible load on column	= 310 × 0·75
	= 232 tons

It should be noted that in these calculations the steel stress used is that permitted for mild steel in reinforced concrete (C.P. 114) and the concrete stress used corresponds to that permitted for 1 : 2 : 4 concrete under the same Code. The concrete should, therefore, conform to the requirements of the 1 : 2 : 4 concrete in the Code and be good for a crushing resistance in twenty-eight-day cubes of 3500 lb per square inch in preliminary tests and 3000 lb per square inch in works tests.

It is submitted that regulations on these lines would appear to be entirely safe. In the tests to be described in a moment the concrete was purposely made not too strong. It was made of 1 part Portland cement, 2 parts of coarse sand and 4 parts of ¾in washed gravel. No special precautions were taken in the way of vibration and an endeavour was made to produce the kind of concrete which could be expected from an ordinary good builder not attempting to take any special precautions.

The test specimens varied from an uncased 10in by 6in joist, 12ft long, which is then progressively encased to give sections 14in by 10in, 24in by 12in, 28in by 14in, and 20in by 20in. This constituted the "A" series. The "B" series was identical except that the joist was a 12in by 8in and the first casing size was made 16in by 12in so as to give 2in casing to the joist, after which they were increased through the same sizes as before up to 20in by 20in. The "C" series was composed of a 12in by 8in joist as before, all the cross sections being the same as in the "B" series, but the lengths of stanchions being increased from 12ft to 18ft.

The larger sizes, from 24in by 12in upwards, numbers 3, 4, 5 and 6, were reinforced with stirrups ¼in diameter at 6in centres. The smaller sizes up to 16in by 12in were reinforced with ⅛in diameter wrapping in a spiral of 6in pitch. In calculating the area of steel the area of the vertical rods provided to hold the stirrups accurately in position was taken into account.

The 1250-ton testing machine used for the tests is capable of testing in tension or compression specimens up to 50ft long with a cross section of 6in diameter or 12in by 3in for tension members and up to 3ft 9in by 3ft 9in for compression members. It is a horizontal machine some 70ft or 80ft in length.

Discussion of the Results

In the author's view this research is not only interesting as indicating perhaps more realistically the true increase in strength which can be obtained in a steel column by casing it, but it also suggests a technique under which certain structures could be run up with quite small stanchions designed only to carry the steelwork of the superstructure, and then while the steel above was going up, the concrete casing could rise from the bottom and give the stanchions the strength they will require to carry their full load.

In this way a great saving in steel can be effected and, furthermore, the drawing-office work could be considerably simplified. Thus, a 10in by 6in stanchion could be provided to carry the load of three or four floors of superstructure even though the 10in by 6in was only strong enough to carry something considerably less than the full total load because the strength of the concrete could be brought into play before the full load has to be carried. In these days when the saving of steel has become a national problem, it is thought this conception may have quite considerable merit.

Suppose, for example, the basis joist in a stanchion is 10in by 5in at 30 lb and the stanchion is subsequently to be cased with 20in by 20in of concrete, we might use eight ¾in vertical rods to support and fix the binding wires, then the carrying capacity of the stanchion after casing would be roughly as follows :—

10in × 5in, 8·85 sq in × 18,000	= 71 tons
Eight ¾in rods 3·52 sq in at 18,000	= 28 tons
387·6 sq in of concrete at 760	= 132 tons
Total	231 tons

On a 13ft height the effective length might be 13 × 0·85in = 11ft and the slenderness ratio 132in/4 = 33.

This gives a safe stress on the ordinary stanchion curve or table of 7·4, so that the reduction factor due to slenderness is 7·4/9 = 0·82. This therefore gives the safe load on the stanchion as 231 × 0·82 = 190 tons.

The steel stanchion required to carry this load at ordinary safe stresses is a 10in by 6in with 12in by ¾in plates weighing 104 lb per foot, as compared with 45½ lb per foot for the 10in by 5in., the eight ¾in rods and the double ¼in diameter links at 6in crs, showing a saving of 58½ lb per foot, i.e. a saving of 56 per cent in the weight of steel.

It is, of course, obvious that each case will have to be considered on its merits, but it is clear that considerable saving can, under favourable circumstances, be effected.

Consideration will have to be given as to how eccentric loading is to be treated with these composite sections. The tests gave no information on this matter and some further work will be necessary, certainly mathematical and possibly also experimental. In the meantime, however, the author is of the opinion that eccentric loadings will not usually produce high stresses owing to the enormous increase of the moment of inertia of the composite section.

The author suggests that if it be desired to take advantage of this approach and the results of the research, the revised regulation 21*b* of the new draft Code might read as follows :—

"*b*. Cased Struts.—Struts of single British Standard I beams to B.S. 4A or British Standard channels back-to-back of symmetrical I form may be designed as cased struts when the following conditions are fulfilled.

"(i) The steel strut is unpainted and solidly encased in ordinary dense concrete with an aggregate not exceeding ¾in and with a works strength not less than 3500 lb per square inch at twenty-eight days when tested in accordance with B.S. 1881.

"(ii) The minimum width of solid casing is equal to $b+4$in, where b is the width of the steel flange in inches.

"(iii) The surface and edges of the steel strut have a concrete cover of not less than 2in.

"(iv) The casing is effectively reinforced with wire at least ⅛in in diameter in the form of stirrups or binding at not more than 6in pitch. When the casing projects outside the steel joist by more than 4in the stirrups or binding must be supported by longitudinal spacing bars not less than 4 in number and not less than 0·8 per cent of the area of the casing. These rods to be not less than ¾in diameter. The cover to these vertical rods to be 1½in. The radius of gyration may be taken as $0{\cdot}2 \times B$, where B is the least diameter of the cased section. The reinforcements to the casing shall comply with Clause 311 of C.P. 114.

"In computing the axial load carried by the cased strut, the whole of the concrete may be taken into account at a stress of 760 lb per square inch, together with the total area of the steel joist and the longitudinal steel rods stressed to 18,000 lb per square inch. So as to take into account the effect of slenderness the total load so arrived at is to be reduced by a reduction factor arrived at as follows :—

"Calculate the slenderness ratio by dividing the effective length of the stanchion by the minimum radius of gyration which may be taken as 0·2 times the minimum diameter of the cased stanchion (or may be calculated accurately as a composite section taking $m=15$). Ascertain what steel stress corresponds to this slenderness ratio from Table 14. This figure, F_s, divided by 9 is the reduction factor previously referred to.

"The steel stanchion must be adequate to carry the total reactions from any one floor without assistance from the casing, but it can be assumed that the load represented by these reactions is spread over the whole cross-section of the composite column before the floor below is reached."

It will be noted that I do not propose to retain the clause that says that the permissible axial load on a cased strut shall not exceed 1·5 times that which would be permitted on the uncased section, nor the clause which requires that these methods of calculation shall not be applied to struts having an overall section greater than 30in by 18in.

In the author's view these clauses are abitrary without scientific justification and go a long way towards destroying the value of composite construction and are in restraint of trade and impossible to justify.

If the revised Clause 21*b* as drafted by me could be agreed and legalised, it would also permit composite construction of steel columns strengthened by concrete encasement to overcome a difficulty which sometimes arises when an existing steel frame building has to be strengthened to carry one or more additional floors or other loads. In such cases it may be extremely difficult or inconvenient to strengthen the existing steel stanchions with steelwork, but may be convenient to strengthen them with concrete encasement in the manner that has already been discussed.

If Regulation 21*b* were left as drafted the amount of strengthening which could be achieved in this way would be so limited as to be of very little use in the majority of cases, whereas if drafted as suggested any reasonable increase in strength of stanchions can be achieved with what would usually be insignificant inconvenience.

For the clause to give the fullest benefit it is, however, quite necessary in the author's view to omit the clause that requires that the permissible axial load shall not exceed 1½ times that which would be permitted on the uncased section, and the clause that requires that these methods shall not be applied to struts having an overall section greater than 30in by 18in.

The short result of this research is to show that composite stanchion construction can be calculated in accordance with the normal rules for reinforced concrete in which the concrete is stressed to 760 lb per square inch and the steel to 18,000 lb per square inch under direct load and eccentric loads can be accepted provided they do not raise the stress on the concrete beyond 1000 lb per square inch. This is a result which is really not very surprising, but it needed verifying on full-scale tests. It opens up a technique in which a very considerable saving of steel in stanchions can be effected, as well as a considerable saving in money in favourable circumstances. It also makes possible the easy strengthening of stanchions in buildings to which it becomes necessary after construction to provide for additional stories or loads, subject to the foundations being adequate.

Book of Reference

Basic Road Statistics, 1955. British Road Federation, 4A, Bloomsbury Square, London, W.1. Price 1s.—The British Road Federation's annual statistical publication on roads and the traffic using them is now becoming widely known as a convenient source of reference. "Basic Road Statistics, 1955" contains statistical information on traffic flow and traffic censuses, road accidents and their cost to the community, vehicles registered, statistics of the transport industry, motor taxation, and data on classified and trunk roads and road finance and expenditure. Historical notes on certain subjects, such as the fuel tax and the road fund, are also given, and there is a section on road transport legislation. Northern Ireland is dealt with in a separate section.

LITERATURE

Jane's Fighting Ships, 1955–56. Edited by R. V. B. BLACKMAN. London : Sampson Low, Marston and Co., Ltd., 25, Gilbert Street, Oxford Street, W.1. Price 84s.

IN view of the revolutionary developments in warships, weapons and equipment since the war, it says much for the editor and publisher that each new edition of *Jane's Fighting Ships* is right up to date—a record which has been consistently maintained since the first issue, fifty-seven years ago. The many newly constructed, converted and modernised ships which are now being added to the navies of the major powers necessitate large numbers of new photographs and a constant revision of notes and data. No less than 450 fresh illustrations appear in the recently published 1955–56 edition, bringing the total number of photographs and drawings to nearly 2700. This has been achieved at no additional cost and with an increase of only eight pages over last year's edition. In the foreword, which summarises the principal changes and developments in the various navies, emphasis is laid on the difficulty most countries are experiencing in building and maintaining the navy they require because of the vastly increased cost of ships, material and equipment. A warship to-day costs about ten times as much as a vessel of similar category built before the war. More open to question is the suggestion that a drastic revision is required in the present classification of warship categories. Admittedly the term "frigate" has now little meaning. Used in the days of sail to denote a reconnaissance ship, it was reintroduced in the second world war to classify an anti-submarine vessel and has since been applied to all kinds and sizes of ships, including, in the United States Navy, vessels of up to 5600 tons built as cruisers or destroyer leaders. But the basic functions of the battleship, the cruiser and the destroyer remain unchanged and are in no way affected by the absence, under present conditions, of the line of battle. Indeed, strict adherence to the line of battle, which was the common practice before Nelson's day, gave little scope for initiative to individual commanders of squadrons.

There is a prevalent belief that guided missile ships are intended to engage enemy vessels with guided rockets, and the foreword does nothing to clarify the position in stating that "three guided missile cruisers have emerged from United States shipyards." The main armament of these ships—as given in the United States section of the book—remains the 8in gun. Two of them have had their after turret replaced by two platforms for launching anti-aircraft guided missiles, while retaining their six 8in guns forward. The third—the "Los Angeles"—retains all her nine 8in guns, but has been fitted with a platform for launching the "Regulus" flying bomb. A reliable and effective ship-to-ship guided rocket is not yet in production in any country. "*Jane's*" credits the Soviet Navy with fourteen "Sverdlov" or modified "Sverdlov" class cruisers already built, with eight more under construction ; also with 400 submarines in commission and another 100 being built. These figures are closely in line with the official Admiralty estimate issued some eighteen months ago. There is, however no suggestion that Russia has, or is developing, submarines with atomic power plants or with engines using hydrogen peroxide and it is scarcely a true picture to say that 16–17 knots is the submerged speed of many of her existing submarines. They are no doubt improved versions of the German type XXI, which were well streamlined with greatly increased battery power. But, however large the battery, its endurance at full output is limited to something less than an hour and a speed of 17 knots for this short period is quite inadequate for present-day requirements.

With the United States Navy concentrating on 60,000-ton carriers—five are shown in "*Jane's*" as being built or authorised—for operating medium-range bombers of the "Canberra" type, it is well that France is now building two carriers similar to but slightly larger than our "Hermes" class. These fast medium-size carriers are likely to be in great demand for the defence of sea communications and for amphibious operations. The Dominion Navies—details of which are given on pages 82–119—are also steadily adding to the naval strength of the free nations. H.M.A.S. "Melbourne," recently completed, and H.M.C.S. "Bonaventure," which should be finished in the year 1956–57, provide both the Royal Australian Navy and the Royal Canadian Navy with a modern, if somewhat slow, carrier, capable of operating "Sea Venoms" and Fairey "Gannet" anti-submarine aircraft. Both navies are also increasing considerably the number of their anti-submarine forces. They are short of cruisers—Australia has only one and Canada two—but no doubt, like Great Britain, they are waiting for the tests of the anti-aircraft guided missile in the "Girdleness" before ordering more ships of this kind. South Africa is also to have a fleet of twenty anti-submarine and minesweeping vessels during the next eight years, all of them to be acquired from Great Britain.

High Vacuum Technique. Third edition. By J. YARWOOD. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 25s.

IN the third edition of this book the author has completely revised the subject-matter and has included many of the high vacuum techniques which have been developed during and since the second world war. The new topics include an extensive analysis of vacuum pumps available from this country and abroad, the gas ballast pump, some discussion of the theory of the diffusion pumps intended rather for the user than the designer, details of large diffusion pumps and systems, new pump fluids, new materials, recent methods of using rubber gaskets, modern types of vacuum valves, innovations in low-pressure techniques, ultra-high vacua, methods of leak detection.

It is a book intended for users of high vacuum systems rather than designers, and for the former, in particular, the section dealing with pumps is extremely useful : the illustrations of pumps are good and would be very useful for students. There is a complete list of most of the pumps available in this country, the U.S.A. and Germany. The sections of the book dealing with the properties of vacuum materials and with applications and techniques are also useful ; they are reasonably complete, although pressure welding is one omission which occurs to us. Some more detailed discussion of glass cold traps would have been worth while as they are devices which are usually constructed by users themselves.

Many kinds of vacuum gauges are described including the new Alpert gauge. This section is open to the criticism that its treatment is rather superficial. For example, it would have been desirable to include sufficiently detailed information to permit readers to construct their own triode ionisation gauges and control units. When mentioning leak hunting methods, the author makes no reference to the differential methods. However, these are criticisms which would apply strictly to the book only if it were intended mainly for experts. For users of vacuum systems and for students this revised edition should prove a valuable reference book : there are few introductory books in this field which are as readable or concise.

Selected Papers on Engineering Mechanics. Edited by G. GABRIELLI, F. N. SCHEUBEL, and F. L. WATTENDORF. London : Butterworths Scientific Publications, 88, Kingsway, W.C.2. Price 50s.

THE innumerable friends and pupils of Professor Theodore von Karman all over the world will be delighted by the publication of this volume of papers by von Karman's colleagues and assistants at the Technische Hochschule at Aachen during his period as Director of the Institute of Aerodynamics (1912–26). The original intention was that the volume should be presented to him on his sixtieth birthday, but some delay was caused by the death of the original editor, Dr. Dirksen. The subject matter of the papers is very various, as it is bound to be after a lapse of a quarter of the century, during which the contributors have become scattered over a number of countries and their attention has turned to new fields. In all there are ten papers, five on various aspects of aerodynamics and fluid flow, two on thermodynamics, two on mechanical properties of materials, and one on theoretical dynamics. All are of a high standard, and it is perhaps not too imaginative to detect in all of them the continuing influence of the powerful and vigorous mind which inspired their authors thirty or forty years ago. The papers are all in English, but German and Italian summaries are given.

No one who has seen von Karman in action in recent years, scattering ideas and enthusiasm in all directions, brushing aside the handicap of deafness as though it did not exist, maintaining with ease his position in the field in which he has been so long pre-eminent, can fail to share the pleasure which he must have felt in this tribute from his old associates.

Books Received

B.B.C. Handbook. London : British Broadcasting Corporation, Broadcasting House, W.1. Price 5s.

The Book of the Lathe. By C. T. Bower. London : Odhams Press, Ltd., 96, Long Acre, W.C.2. Price 15s.

Law and the Engineer. By C. F. Mayson. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 63s.

Diesel Operation and Fault Diagnosis. By Gerald B. Fox. London : Odhams Press, Ltd., 96, Long Acre, W.C.2. Price 21s.

Industrial Furnaces. Vol. II. Third edition. By W. Trinks. London : Chapman and Hall, Ltd., 37, Essex Street, W.C.2. Price 80s.

Electricity Undertakings of the World, 1955–56. London : Benn Brothers, Ltd., Bouverie House, 154, Fleet Street, E.C.4. Price 30s.

Dynamics in Machines. By F. R. Erskine Crossley. New York : The Ronald Press Company, 15, East 26th Street, New York, 10. Price 7 dollars.

British Nuclear Energy Conference

The inaugural meeting of the British Nuclear Energy Conference was held at the Institution of Civil Engineers, London, on Wednesday, November 30th, under the chairmanship of Sir Christopher Hinton. In his opening address Sir Christopher outlined the origins and aims of the conference. Four lectures were then presented for discussion: Sir John Cockcroft dealt with the U.K. Atomic Energy Authority and its functions; Messrs. V. A. Pask and J. C. Duckworth discussed the place of nuclear energy in U.K. power development; Mr. H. J. Grout spoke about the use of research reactors in nuclear power development; and Dr. A. S. McLean and Dr. W. H. Marley dealt with health and safety in a nuclear power industry. The following account of the first part of the proceedings is concerned mainly with an abstract of the discussion of the paper by Messrs. Pask and Duckworth; an abstract of the paper itself appears on page 828.

Chairman's Address

SIR CHRISTOPHER HINTON: It was about ten years ago that the first steps were being taken to build up an atomic energy organisation in Great Britain. The new industry spent the first eight years of its life almost entirely in meeting military demands, and during that time it worked behind a curtain of secrecy. But now nuclear engineering has emerged from that stage and is established by the White Paper plan, published in the spring of this year, as an important industry in its own right, an industry on which £300 million will be spent in Great Britain alone, between now and 1965, and on which, by 1975, the expenditure in the home markets will amount to something between £200 million and £300 million a year.

It is important that we should get this new business into its correct perspective. We must not regard it as being a completely new technology. It is rather an extension and a development of existing technologies. In the nuclear power stations which are now being built or designed one-third of the expenditure is on plant which is strictly conventional in design and construction and which might be found in any other power station. In the remaining two-thirds the materials and many of the techniques of construction are conventional. Indeed, we ought to attribute this country's present satisfactory position in the field of nuclear energy, not to the ability to forge technologies which are completely new and revolutionary, but rather to the ability which has been shown in adapting and developing existing techniques to problems which are completely new. This is exactly what happened in the early days of the conventional steam engine. In the past, when new technologies have been evolved in the world of engineering, there has been a tendency to form new institutions to serve the interests of the engineers engaged in the new field. This might quite well have happened in connection with nuclear engineering, but such a development would have had many disadvantages; instead, in this case, five great institutions—the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institute of Physics, and the Institution of Chemical Engineers—have formed collaborative arrangements which they feel will best cover the interests of engineers and applied scientists working in atomic energy. Each of these institutions nominates three members to the governing body of the Conference. The objects of the Conference are to assist the constituent bodies in co-ordinating their activities in nuclear engineering, to arrange meetings which are open to all members of the constituent bodies, to assist in obtaining papers on subjects related to this field, and to arrange for the printing and publication of those papers in the *Journal of Nuclear Energy*. The first number of this *Journal* will be published in January, 1956. Also among its objects is the promotion of symposia or conferences on a national or an international basis for the discussion of nuclear energy problems.

The Conference aims, above all things, at achieving its objects without in any way abrogating from the constituent institutions any of the responsibilities which those institutions hold individually. It aims at being a collaborating rather than a controlling body.

The United Kingdom Atomic Energy Project

In his lecture on the United Kingdom atomic energy project, Sir John Cockcroft, Director of the Harwell Research Station, said that an essential feature of the graphite-moderated reactors, which the White Paper referred to as stage-1 reactors, was that they would produce plutonium as a by-product that could be stockpiled and used for more highly rated reactors requiring enriched fuel in stage 2 or stage 3 of the programme. The White Paper envisaged a change to the more highly rated reactors of stage 2 towards the end of the ten-year period. Higher ratings—up to 5MW (electrical) per ton of uranium—could probably be achieved by using water or liquid sodium as the heat transfer medium. Present feeling at the U.K.A.E.A. was that resources could be found by the Authority for only one stage-2 reactor.

Stage 3 of the programme aimed at breeding, either by homogeneous reactors using the ^{233}U-Th fuel cycle, or the fast reactor using the ^{239}Pu–^{238}U fuel cycle. Although work was proceeding vigorously on stage-3 reactors, it was thought that the development period would be long, and a large-scale contribution to nuclear power from such breeders was likely to be in the 1970s rather than the 1960s.

Dealing with the procedure in development of new reactors, Sir John said that industry was associated with each stage of reactor studies. At Harwell forty-two representatives of industrial organisations were taking part in reactor studies at the research or feasibility stage. Representatives of C.E.A. and two industrial groups were now helping with the design study of the pressurised-water reactor. The Industrial Group was working closely with four industrial organisations on the design of the C.E.A. stage-1 graphite-moderated power stations. The design proceeded independently in the separate organisations, but regular meetings to co-ordinate the effort were held to discuss common problems and the contribution of the Authority to the development work. The homogeneous reactor, which was part of the stage-3 programme, was being studied with the help of the chemical industry, since this reactor would be a highly specialised chemical plant with built-in facilities for continuous chemical processing of fuel.

Industry was also taking a major part in the design and construction of the new research reactors DIDO and PLUTO and had already obtained an overseas order for one of these. Another industrial organisation was prepared to build swimming-pool types of reactors. The export of such reactors would be limited by the availability of enriched fuel.

The production of uranium fuel and the processing of spent fuel was likely to continue to be the responsibility of the U.K.A.E.A. Development of fuel elements which would withstand the irradiation damage during the long burn-up period was probably the most difficult task in the whole programme. Water reactors were likely to use uranium-oxide fuel elements as their main charge, since such elements were not attacked by hot water. If an ordinary light-water moderator was used, however, the reactor fuel must be "spiked" by ^{235}U or plutonium. Plutonium would be used to spike the stage-2 reactors, as soon as the stage-1 reactors had produced enough. Thus plutonium-based fuel elements would also be required; perhaps plutonium-oxide would prove to have as good properties as uranium-oxide.

Sodium-graphite reactors would be able to use uranium metal since this was compatible with liquid sodium. Whatever fuel elements were required, they needed prolonged testing in large numbers in the development period. The processing of spent fuel elements was at present undertaken mainly at Windscale by the aqueous-solvent experimental process.

The details of the fuel-element design had a marked effect on the character of the chemical separation process. Experience had shown that costs of chemical processing fell rapidly with the increase in the scale of operations. It seemed likely that the existing U.K.A.E.A. factory would be adequate to deal with the programme of nuclear power up to 1975. It was also expected that the U.K.A.E.A. would be able to provide natural uranium fuel for the reactors which might be exported in the 1960s and willing to undertake the processing of spent fuel.

The possible field of application of radiation to industrial processes was wide and a radiation-using industry might well develop. Applications to industrial processes such as the polymerisation of ethylene to polyethylene were now well known, but their commercial advantages compared with well-tried high-temperature, high-pressure processes were not clear. The improvement of the high-temperature properties of polyethylene was another well-known example. The production of hydrogenation and oxidation reactions and many organic reactions were being studied. A Technological Irradiation Group at Harwell assisted industry to study these possibilities by providing at Harwell intense sources of radiation from fission products, reactors and accelerators. About thirty investigations were at present proceeding on behalf of industry.

Place of Nuclear Energy in U.K. Power Development

In their lecture on the place of nuclear energy in U.K. power development, Mr. V. A. Pask and Mr. J. C. Duckworth attempted to forecast the pattern of progress in the next two or three decades. They suggested that the White Paper nuclear power programme would provide no more than half the additional generating capacity that would be needed to make good the anticipated deficiency of coal by 1965. They analysed costs

of nuclear power generation and concluded that nuclear power might eventually result in cheaper electricity. Dealing with the question of load factor improvement, the authors suggested that pumped storage would become increasingly attractive as more of the base load came to be generated by nuclear plant.

An abstract of this lecture is reproduced on page 828. Four speakers were invited to take part in the discussion of this lecture and abstracts of this discussion are given below.

Discussion

Mr. J. Eccles (Central Electricity Authority) : In the brief period allowed for discussion I propose to indicate some of the wider problems which require to be understood, if not wholly solved, by those who carry the main responsibility for furnishing an adequate supply of electricity in Great Britain.

The first question is : What is likely to be the magnitude of the electrical demand ? Assuming full employment and a steady increase in mechanisation of industrial processes and an attainable increase in productivity, it has been estimated that the energy required by 1980—expressed in tons of coal—whether as coal, oil, hydro-electric, coal or gas, will be of the order of 400 million equivalent tons of coal per annum, or a little less (the actual figure for 1955 is 255 million tons). Personally, I think this is a maximum requirement and that, allowing for improved use of fuel and the limiting effect of world markets for manufactured goods, the total might be lower. However, accepting it for the moment, it is thought that of this total, 135 million equivalent tons may be required as oil (in all forms), 120 million equivalent tons as electricity, and 140 million tons as gas and solid fuel.

By 1980—the period covered by the paper—the total inland coal mined might not exceed 225 million tons per annum, so it will be necessary somehow to bridge the gap in total energy requirements in this country between 225 million and something of the order of 400 million equivalent tons. By simple arithmetic the proportion of the 225 million tons per annum available for electricity production is 85,000,000 tons, if all the oil is to be imported. Allowing, say, 2,000,000 tons for hydro-electric energy, it will be seen that nuclear energy may be required to produce electricity equivalent to 33,000,000 tons of coal.

In my judgment, this forms the lower limit to the nuclear power programme over the next twenty-five years. The upper limit will be set by the technical and manufacturing ability to produce economical nuclear power stations and by the economic attractiveness of this form of fuel as compared with, say, imported oil. It might well be that by 1980 the world oil supply might be feeling the strain of increased demand, and if that should be so, or indeed if this country should feel that it is unable or unwilling to import oil to the tune of the equivalent of 135 million tons of coal, then the production of oil from coal at home might very well be tried. This is quite an attractive possibility, and if I put a pure guess of about 50,000,000 tons of coal being converted into oil by 1980, this would leave an upper limit of 33,000,000 plus 50,000,000 namely, 83,000,000 tons equivalent by 1980 to be produced by nuclear power. This is on the assumption that the 50,000,000 tons of coal would be taken away from the electricity coal programme and handed over for fuel processing. There is therefore a balance of between 33,000,000 tons coal equivalent and 83,000,000 tons coal equivalent at about 1980. The authors have based their estimate on 62,000,000 tons of coal equivalent from nuclear power, so that they have come well within the balance that I have postulated.

Having settled these parameters, the next thing that the Central Electricity Authority has to do is to be quite certain that this fuel will be available, not only in 1960, 1970 and 1980, but for all foreseeable time, because they are committing themselves to a very heavy capital programme.

The quantity of this fuel employed will be greater, and its irradiation limit lower, in the early reactors than in the subsequent designs and, when one-to-one effective breeding is achieved, the quantity of new fertile material to be fed into the system will be relatively small. Nevertheless, it is necessary to have an assurance that fuel supplies equal to the maximum requirements will be secure for a very long time to come.

Turning now to the more detailed problems of management, we may ask whether it is physically possible to create nuclear power stations at the rate envisaged in the paper ? In effect, the authors say that twenty 200MW stations are required to be in operation by 1965, a further eleven by 1970, a further thirty-five by 1975, and a further forty-nine by 1980, making a grand total of 115 stations. Of course, if the stations are bigger, there will be fewer of them ; but, taking 200MW as a rough basis, in the five years from 1975 to 1980 nuclear stations will require to be commissioned at the rate of ten a year.

The programme in the authors' paper is about twice the White Paper programme up to 1965, and I, personally, think that it will be well-nigh impossible in the early stages of a development programme of this kind to meet the whole of the deficit by nuclear energy. This is why the Central Electricity Authority has entered into contracts for the use of oil as a fuel in conventional stations, to bridge this particular gap. I do not feel that the programme is unrealistic in the later years, but if one adds the export business which may well be achieved in this field, it is important that all concerned should set out their stalls to cater for it.

For the electricity supply authorities there is the problem of finding suitable sites for 115 nuclear stations during the next twenty years, and the training of personnel to design, operate and maintain these stations. A good deal of public relations work of the right type will be required to educate the public on the need for these stations.

The supply of technical manpower may set a limit to the rate of progress. On the other hand, as world knowledge accumulates, it should not be necessary to build more than a research prototype of the later models before going into commercial production.

The economics of nuclear power production centre round the capital cost per kilowatt of the nuclear stations, the life of those stations, and the net cost of fuel. The net cost of fuel is of prime importance. So long as the useful by-product, plutonium, produced in the electricity supply authorities' commercial reactors is not being used in commercial reactors under the same ownership, then it must be credited at its full net value. Indeed, from what Sir John has said, there might be a credit coming for isotopes as well ! However, this is a fundamental point with those who are making the investment that creates such a valuable by-product.

The authors quote figures for the credit likely to accrue from this source : on this basis, the resultant net cost of replacement fuel is zero in a 200MW reactor at a radiation of 3000MWD (megawatt-days) per tonne.

I have translated the authors' calculations for this size and type of reactor, with and without a credit for plutonium, into curves showing cost per unit against load factor. These curves show that even with full credit for plutonium nuclear electricity is more expensive than that derived from present-day coal at load factors below 56 per cent. This is entirely due to the high capital cost of the nuclear station, and it underlines the need for an all-out effort to reduce the investment per megawatt and to get full credit for plutonium if these stations are to be competitive for two-shift and, ultimately, for single-shift operation.

Mr. G. F. Kennedy (Messrs. Kennedy and Donkin) : There seem to be three main reasons for the rapid development of nuclear power plant on a large scale in this country. These are (i) the short-term need to bridge the gap between available coal production and the increasing demand for electrical power ; (ii) the long-term need to generate the whole of the country's requirements of electricity from sources other than fossil fuel, which would allow our remaining reserves of coal to be conserved for use in carbonising and gasification processes ; (iii) the need to develop nuclear power plants suitable for export requirements, so that our manufacturers might capture as large a proportion as possible of the world market for this type of plant.

Messrs. Pask and Duckworth have produced fairly convincing arguments to show that the early graphite-moderated, gas-cooled reactor stations should produce electricity at a cost comparable with the present-day production costs in large coal-fired stations. Even if the 60,000,000 tons of coal which the Central Electricity Authority assume will be available to them annually by 1970 materialise—which I feel might be open to some doubt—it seems clear that the cost of that coal might be substantially higher than it is to-day. It follows, therefore, that nuclear energy might in fact become competitive with that obtained from coal in the early 1960s, and if this should be so, it would be important to the economics of power supply in this country to step up the rate of building nuclear reactor stations as quickly as possible.

With regard to exports, I suggest that urgent consideration should be given to the construction of moderate sized commercial prototype reactors intermediate between the gas-cooled and fast fission reactors. The construction of such reactors should, in my opinion, be pressed forward concurrently with the Central Electricity Authority's programme of graphite-moderated, gas-cooled reactors so that those concerned with exports—consulting engineers and manufacturers alike—might have first-hand experience of the design, construction and operation of such units, without which it will be difficult to impress overseas customers.

The authors have rightly touched upon the importance of improving load factor and of the effect which peak-load pumped storage plant could have in improving the load factor of base load stations. With high capital and low works cost stations, it will be increasingly important in the future to improve system load factor by every possible means, including the reintroduction of special tariffs for off-peak consumers. Railway electrification could also play an important part here by running schedules of heavily loaded freight trains at night.

Mr. A. L. G. Lindley (General Electric Company, Ltd.) : The development of the plans outlined in the paper is not a case of simply deciding the time and extent of entry of nuclear power into the country's generation programme. It is basically a major

engineering project which has been taken up by industry, and in my contribution to the discussion I want to refer to the part which industry has to play in the development of nuclear energy and future power generation and also outline what it means to industry to create the effort necessary to ensure success.

It was only two years ago that a definite move was made to bring the resources of industry into the development of future nuclear power generation, and at that time industry had little knowledge with regard to the nuclear side, but a wealth of knowledge with regard to the conventional generation sections of nuclear stations.

It was foreshadowed that there would be rapid development in the direction of building prototype stations in the coming ten years. There was some urgency, therefore, in the need for industry to lose no time in taking up that new branch of engineering.

It is clear that the role which industry must take is that of going forward with reactor development starting from the lead given by the Atomic Energy Authority with the Calder Hall project. That project virtually pilots the form and character of the first-stage power stations, although many well-established techniques developed by industry have been used by the Authority in its construction. It is realised by industry and the two Authorities that there can be no short cut in following that lead, and there is indeed a great deal of ground to be covered if we are to reach some of the far-reaching developments such as those outlined in the lecture, which mentioned the primary heat of future power stations being generated in a space no greater than 2ft diameter by 2ft in length. The immediate or first stage of the programme was made known in the Government White Paper published early this year, and that places a very heavy responsibility on industry, not only with regard to construction, but with respect to new designs, research and development which are vitally necessary if that programme is to be carried through.

The necessary change of effort involves an unusually heavy demand for men with highly specialised experience. It has become evident that there are not enough men in the country to man the effort and at the same time maintain the pace on other work. To go forward with nuclear power, therefore, sacrifices have had to be made in the electrical industry, and men with specialised knowledge have been transferred to take up nuclear power work.

A statement issued only yesterday from Government circles emphasises that the universities to-day are producing insufficient graduates to meet the nation's requirements in new development, including nuclear energy, and what this really means is that the overall rate of progress which is being attempted is outstripping the country's ability or willingness to train men to make that progress possible. The nuclear power programme will, of course, expand a long way beyond the White Paper stage, and an increasing number of technically trained personnel will be required to meet that expansion. There is, in fact, a strong case now for industry and educationists to come together and to agree on some plan which will produce those men within the required time.

The Government White Paper clearly requires industry to make a special effort to put down four stations of an improved design by 1960–61, and it is imperative, therefore, for industry to accelerate plans for working out those designs. I believe I am right in saying that the four firms engaged in this nuclear power development have spared no effort to make that possible. Much progress has been made and in certain directions where there has been a particular scarcity of knowledge, basic and long-term research is in progress. The effort put into this and the design programme is, of necessity, very substantial, and it is important to see that this effort is not wasted. In this respect consideration should be given to the financial burden which industry has had to accept to make possible the rapid development needed. Money is not readily available to industry for this purpose, although the Chancellor has made it clear that it will be made available to the purchasing authority.

I have studied the figures set out in the lecture with regard to cost of power generation with great interest, and, in so doing, wondered how far those costs really have to be taken into account in the development of nuclear power. The stark fact that we have to appreciate is that we must have electrical power in ever increasing quantity, in spite of the decline in availability of conventional fuel, if we are to satisfy the need of our expanding economy and rising living standards.

As far as we can see at present nuclear fuel will largely have to take the place of fossil fuel in the long run, whatever the cost of electricity generation. It is as well to recognise that now, and to appreciate that the phase through which we are now passing is long-term development leading to the time when fossil fuels will only be used sparingly for essential processes.

Sir Claude Gibb (Nuclear Power Plant Company, Ltd.) : I wish first to deal with the point raised by Mr. Eccles as to whether industry is capable of dealing with the programme envisaged by the authors. The answer is that I am quite certain that industry can do it, and must do it, if the nation is to survive. The technical effort required to produce an equivalent number of megawatts sent out is not very different whether it is done by nuclear or fuel-fired stations.

The cruel fact is that there will not be in the 1960s, and after, sufficient coal produced in Britain to meet the needs of those basic industries such as iron and steel and certain chemical branches (where coal is a basic chemical element as well as a source of heat), and the electricity supply industry, if the latter is to keep pace with a continuous desire and pressure for an ever improving living standard.

The authors, being subject to a certain amount of ministerial direction, were understandably a little shy in stating outright that nuclear power would be the salvation of the electricity supply industry and thereby of the country's national standard of living. That the authors envisage a rate of growth of nuclear plant far greater than proposed in the Government White Paper is a great encouragement to those who have studied the demand and supply position of British coal.

The not very distant future will demonstrate fully the vision of the chairman, Sir Christopher Hinton, and Sir John Cockcroft and their colleagues, when they decided to build gas-cooled reactors at Calder Hall, thus to become the prototypes for the true industrial development of nuclear power. Such reactors—gas-cooled, graphite-moderated—are economical and competitive with modern coal-fired power stations only when they have a relatively large output, and in that sense they might well be unsuitable for export needs in the immediate future. However, those who have made a close study of the export possibilities in the immediate future are not anything like so optimistic as they were a year ago or as Mr. Kennedy appears to be. Gas-cooled reactors are, however, ideally suited for the immediate needs of Britain, and they will not be outmoded or made obsolescent by subsequent developments of reactors requiring enriched fuels. A considerable number of reactors utilising natural uranium as the primary fuel will always be required.

Developments in metallurgy and in basic heat transfer techniques, when applied to gas-cooled reactors, will allow higher operating temperatures at modest gas pressures, with consequent improvements in cycle efficiency and reductions in generating costs. The concentration of effort by the Atomic Energy Authority upon gas-cooled reactors for the first prototype and commercial nuclear power stations will be proved to have been the correct policy and to give Britain a commanding lead in that new field.

The cost analysis prepared by the authors is, I am sure, sensible and realistic in the light of present-day knowledge. Much depends, as has been pointed out, on the extent of irradiation which can be obtained from canned fuel elements, and much, of course, on the value ascribed to plutonium. I do not think we should be unduly disturbed by the potentially higher cost of canning plutonium containing fuel. The main burden may well consist of natural fuel with spears of the plutonium enriched material distributed as required.

I am glad the authors drew attention to the considerable benefits which accrue from the use of thorium as a fuel. Invaluable as it has been in giving the beginning of the nuclear age, the small amount of U_{235} occurring in natural uranium should not blind us to the advantages of thorium and its use in the production of U_{233} in the Authority's nuclear stations.

The authors have rightly given serious consideration to the improvement in system load factor. As the proportion of the load carried by the highly capitalised nuclear plant increases that matter will become of paramount importance. Shift working by industry is desirable, if not essential, in the national economy, and industry and the community as a whole has yet to face up to and accept the social disturbance arising from shift working. One of the authors at least knows the very strong views that I hold on the question of attractive tariffs to encourage off-peak electric thermal storage heating for industry and the home as a means of load building. It is to be hoped that the commercial division of the Central Electricity Authority will read the paper and develop a greater appreciation of the urgent need to begin building load factor now.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

HELICAL AND VOLUTE SPRINGS AND SPRING STEEL (RAILWAY ROLLING STOCK MATERIAL)

No. 24, Part 3B : 1955. Price 4s.—The revision of B.S. 24, Part 3, "Springs and Spring Steel," has been in hand for some time, and the specification for laminated springs and for the flat bars from which they are manufactured are still under consideration. Since agreement had been reached on the requirements for helical and volute springs and for the bars for their manufacture, it was decided to issue this part of the standard separately. The new standard specifies the following :—Hot rolled spring steel bars for helical and volute springs ; helical and volute springs made from the above material ; steel helical springs cold coiled from a drawn material ; ground spring steel bars for helical springs, and helical springs made from round section ground steel bars. Also covered are the chemical compositions of the steels, the quality of the material, and the tolerances to which these springs are to be made. The Appendix contains the recommended method for calculating the total number of coils for helical compression springs.

Machinery at the Smithfield Show

No. II—(*Concluded from page 798, December 2nd*)

THE Smithfield Show and Agricultural Machinery Exhibition opened at Earls Court, London, last Monday morning, and will close this (Friday) evening. Throughout the week there have been, as always, numerous visitors to the show, both from this country and overseas, and there is plenty of evidence that there is no lessening of interest in the many aspects of modern agriculture. The cattle, sheep and pigs have been carefully scrutinised by experts and amateurs alike, and the large portion of the exhibition area taken up by machinery and implements has attracted a great deal of attention. We conclude here our account of some of the many exhibits in the machinery section.

The latest addition to the tractors made in this country by International Harvester Company of Great Britain, Ltd., 259, City Road, London, E.C.1, is illustrated by Fig. 4. It is shortly to be put into production at the Jowett works at Bradford, which the company acquired about a year ago. The tractor, which is called the B-250, has a diesel engine rated at 30 b.h.p., is fitted with Lambert disc brakes, has a differential lock to prevent wheel slip, and is equipped with a reversible linkage arrangement enabling the use of different categories of mounted implements. The B-250 shows a "tidy" design, and its bonnet and radiator grille can be pivoted forward to disclose the engine, radiator, air cleaner and batteries. The controls are well placed, a foot platform is provided on each side of the driver's seat for safety, and the seat itself is adjustable to suit the length of the driver's leg.

The four-cylinder diesel engine, 3⅜in bore and 4in stroke, has a maximum governed speed at full load of 1750 r.p.m. A 12V electric system with manual engagement is used for starting, assisted by glow-plug heating of the precombustion chambers. There is a single-plate 10in clutch, and the gearing is arranged to give five forward speeds between 1·11 and 11·42 m.p.h. and a reverse speed of 2·23 m.p.h. The wheelbase of the tractor is 6ft 2½in and the turning radius with the brakes applied is 10ft 3in. The standard equipment of the tractor includes a rigid drawbar, which is adjustable for height, and a swinging drawbar. With the hydraulic three-point linkage there is included a system of weight transfer, which enables implement weight to be transferred through the link arms to the tractor's back axle. By means of a landwheel a drop-limit can be set on the link arms, and implement weight thus taken off the landwheel. With this system, therefore, implements can be used with or without a landwheel. The power take-off shaft fitted to the B-250 has a maximum speed at full load of 531 r.p.m., and there is also a belt pulley, the maximum full-load speed of which is 1251 r.p.m.

The tractors exhibited by the Ford Motor Company, Ltd., are the several versions of the wheeled and crawler Fordson "Major." The crawlers include an example of the "Roadless J.17" full-track tractor which is a "Major", diesel fitted with rubber-jointed tracks made by Roadless Traction, Ltd., Hounslow, Middlesex. The ground plates are 14in wide and the track centres 53in. An item of particular interest on the Ford stand is a summarised report of a ploughing test performed over a period of six days and nights in Suffolk. A "Major" diesel wheeled tractor with preset linkage control, operated a four-furrow plough for a continuous period of 144 hours. The average depth of ploughing was 7½in, the total area ploughed was 283·7 acres, and the total fuel used was 215·2 gallons. It is stated that during the test the implement linkage was raised and lowered over 2000 times and the length of furrow ploughed was about 2400 miles!

On the stand occupied by Massey-Harris-Ferguson, Ltd., Coventry, there is displayed a Ferguson tractor which has worked for a year in the Antarctic with the Australian Department of External Affairs Antarctic Survey. The log book kept by the chief engineer shows that the tractor was operated on general haulage for 565 hours. The exhibit is interesting in view of the fact that some Ferguson diesel-engined tractors are now on their way to the Antarctic for use by the Commonwealth Expedition which is led by Dr. Fuchs. These tractors have been fitted with specially designed half-tracks, and with skis which replace the front wheels.

Engines

In recent years there has been increasing use made of stationary oil engines in agriculture. They provide power for the variety of barn and other machinery installed by farmers, and it has been estimated that round about 250,000 stationary engines of one kind or another are now employed in British agriculture. There are several such engines exhibited at Earls Court.

An engine, which makes its first appearance at the show, is the three-cylinder diesel (Fig. 5), produced by Armstrong Siddeley Motors, Ltd., Coventry. It is an air-cooled engine which follows the lines of the firm's single and twin-cylinder diesels, many of the parts being interchangeable; the power range is from 20 b.h.p. at 1000 r.p.m. to 33 b.h.p. at 1800 r.p.m. The drive can be taken from either end of the crankshaft or from the specially strengthened camshaft which protrudes from the front cover. The principal details of the engine are: bore and stroke, 4·25in; cubic capacity, 180·9 cubic inches; compression ratio, 15 : 1; fuel tank capacity, 7·75 gallons; and weight, 970 lb.

The combustion system is direct injection with a hemispherical bowl formed in the silicon-aluminium alloy piston crown. The piston is fitted with three compression rings, two scraper rings, and a fully floating gudgeon pin. The engine has C.A.V. injection equipment, the fuel pumps being operated from the camshaft by rocker levers. The lubrication system includes a rotary pump, which draws oil through a strainer in the crankcase and delivers it to the main oil gallery through a Tecalemit filter. Oil is fed from the gallery under pressure to the crankshaft, camshaft and connecting-rod big end bearings. An external pipe feeds oil from the camshaft bearings to the rocker gear, and the cylinder bores and gudgeon pins, &c., are splash lubricated from the big end bearing.

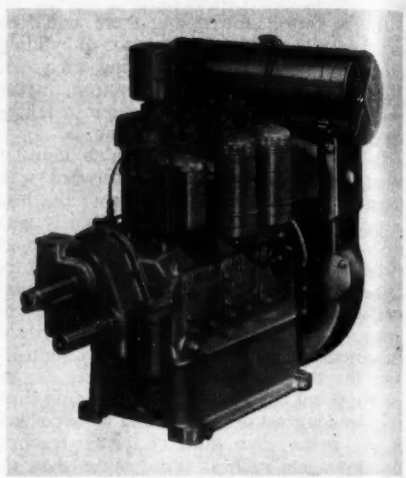


Fig. 5—Three-cylinder air-cooled diesel engine with power range from 20 to 33 b.h.p.

Some new diesel power packs, suitable for application to agricultural machinery and industrial plant, are shown by Newage (Manchester), Ltd., Crossley Street, Gorton, Manchester, 18. There are 3·4 litre and 5·1 litre packs, each unit being complete with a radiator of temperate or tropical capacity, fuel tank, silencer, shaft extension, and electric starting equipment. The canopies are hinged so that the engine and all its component parts are readily accessible for maintenance. The 3·4 litre pack gives outputs varying from 27 b.h.p. at 1200 r.p.m. to 42 b.h.p. at 2000 r.p.m., whilst the 5·1 litre engine ranges from 40 b.h.p. at 1200 r.p.m. to 63 b.h.p. at 2000 r.p.m.

Field and Barn Equipment

The implements displayed at the Smithfield Show cover just about every aspect of modern farming. Our inspection of the many items of equipment leaves us with the impression that the agricultural engineering industry is giving increasing attention to the requirements of smaller farms without in any way neglecting the needs of larger acreages. Mechanical handling is now as important on the farm as it is in industry generally, and in the post-war years many tractor-operated loaders and lifters have been designed. Most of them are worked by the hydraulic lift system of the tractors on which they are assembled. A departure from that practice is shown in Fig. 6, which illustrates the "Multilode" tractor loader just introduced by E. V. Twose (Manufacturing), Ltd., Tiverton, Devon. This loader does not use the tractor's hydraulic system or an auxiliary engine. The loader itself consists of a framework attached to steel shafts which are bolted to the

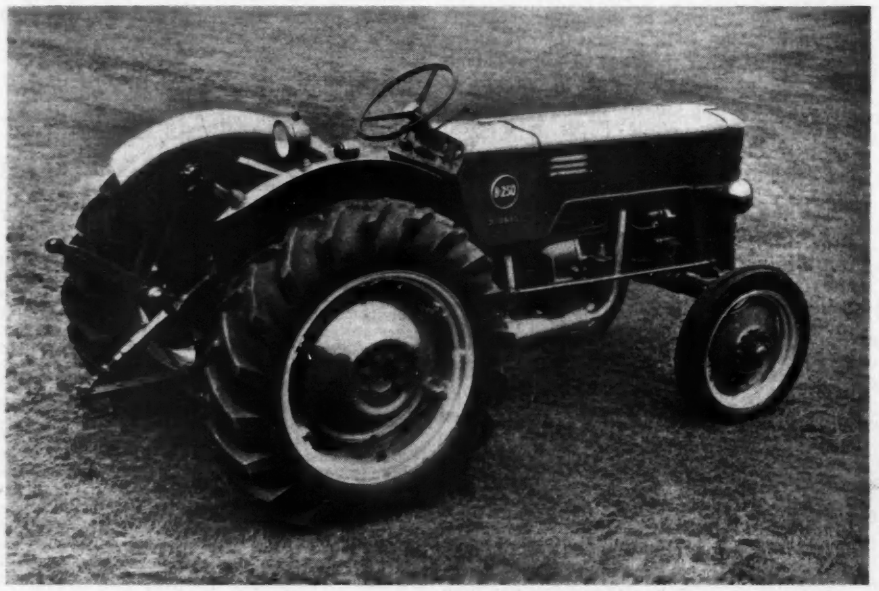


Fig. 4—30 b.h.p. diesel-engined tractor fitted with disc brakes and differential lock

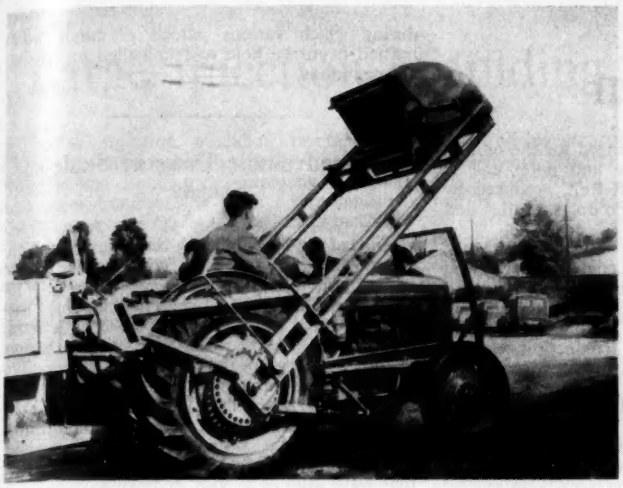


Fig. 6—The "Multilode" tractor loader. Its framework is bolted to the hubs of the tractor's back wheels

Fig. 7—Planter for "fluffy" cotton seed. A picker wheel conveys the seed to the coulter pipe.

hubs of the tractor's back wheels, on either side. The rake tines or loading bucket, whichever is required for use, are bolted on to the front part of the frame. The method of operation is to lock the framework to the back wheels and reverse the tractor until the tines or bucket are immediately above the trailer hitched behind. In completing this part of the operation the loader moves about 4ft. There are triangular legs on either side of the framework, which make contact with the ground and thus stop any further movement of the framework when it reaches the correct tipping position above the trailer. When the tractor is again put into a forward gear the framework returns to its original position. The bucket or tines can be tripped both in the forward and rear positions, and there is provision on the framework for holding the loader in a number of different raised positions for transport and other purposes. It should be noted that in order not to overload the transmission of the tractor counterbalanced springs are fitted to the framework so that actually the tractor only lifts the weight of the loaded bucket or tines. The makers claim that the framework and loader can be assembled on or dismantled from the tractor in less than a quarter of an hour.

Another new product exhibited by E. V. Twose, Ltd., is a root gapper, which is available as a complete machine fitted with universal linkage or as an attachment to the firm's toolbar frame. Each unit of this machine—there are three, four and five-row models—is spring-loaded and comprises a pneumatic wheel and a slotted gapping disc. The discs and wheels are fully adjustable in their respective clamps. The method of operation is very simple; the pneumatic wheel provides a positive friction drive to the gapping disc and keeps it at the right depth of work.

In Fig. 7 there is shown a planter which, amongst other seeds, has been designed to deal with undelinted or "fluffy" cotton seed, and with maize or ground nuts. The planter is made by David Brown Tractors (Engineering), Ltd., Huddersfield, and is in fact assembled on a David Brown Albion toolbar. For normal work there are two planter units, each consisting of a twin-boom frame upon which is mounted the seed hopper. When the planter is used for undelinted cotton seed, a hopper containing a horizontally revolving friction plate is mounted on the frame. The plate is fitted with teasing hooks, which feed the seed clusters to a picker wheel. The picker wheel conveys the seed through a spring-loaded gate to the coulter pipe and thence to the ground. Power for the various working parts is provided by a steel paddle wheel; a chain activates the cross-drive shaft and secondary chains transfer the drive to the individual planting units.

A tool of a very different sort, which has made its first appearance at the show, is a slashing machine (Fig. 9) for potato haulm, bracken, kale stalks, or tall weed growth. It has been designed and produced by Wolseley Engineering, Ltd., Electric Avenue, Witton, Birmingham, 6, and is appropriately named the "Swipe." The machine exhibited is attached to a Ferguson tractor and takes its drive by a vee belt from the tractor pulley. The arrangement of the "Swipe" is simple; it consists merely of an upright shaft, mounted in ball bearings, three steel chains being fitted to the bottom of the shaft. When the shaft is rotating at high speed the chains swing out under their own weight and literally slash the growth being cleared. The slasher, which makes a 4ft swath, can be offset to work outside the tractor wheels for such jobs as trimming the bottom of a hedgerow.

With the great increase in the use of combine-harvesters in this country, the matter of grain drying has become more and more important to farmers, and in particular to those farmers who are dealing with the smaller acreages. With the requirements of the smaller farms in mind, Ransomes, Sims and Jefferies, Ltd., Orwell Works, Ipswich, has produced a vertical grain drier (Fig. 8) which needs no foundation work for its assembly. The warm air is provided by a thermostatically controlled oil-fired furnace. The grain is elevated from the receiving hopper and discharged into the intake at the top of the drier. It is distributed by a worm conveyor, and moves uniformly in a controlled bed, 4in deep, over inclined perforated plates. The inclination of these plates is such that, in the main drying section—approximately in the centre of the equipment—the grain is uncovered and open to inspection during the drying process.

Fig. 9—A general-purpose slashing machine which can make a 4ft swath

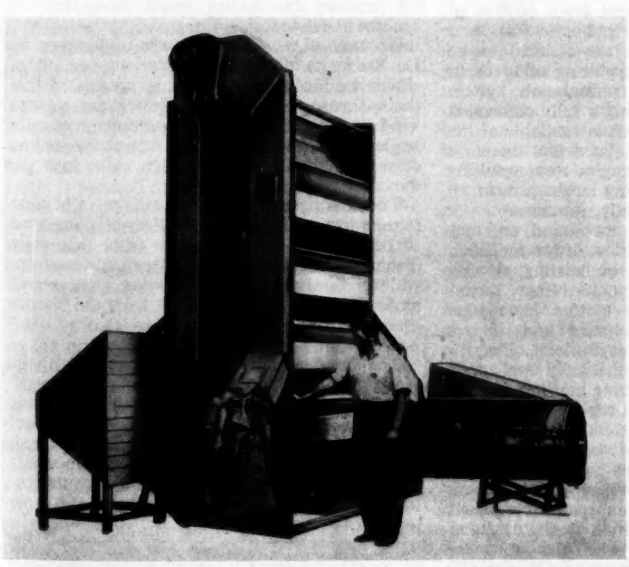


Fig. 8—Gravity flow grain drier operated by an 8 h.p. electric motor

In the bottom section of the drier the grain is cooled by the use of an extraction fan, the outlet from which is connected to the top section of the drier; the spent heat from the cooling section is thus reclaimed to provide a preheating section at the top of the drier. There is a hand screw for varying the rate of grain flow through the drier, and the discharge of the grain is controlled by an oscillating valve. The dried grain is collected by a worm conveyor and elevated to the bagging hopper. For driving the moving parts of the drier an 8 h.p. electric motor is included in the outfit, although a countershaft for an oil engine drive can be supplied as an alternative. The drier does not require a great deal of space for assembly, which is an important consideration at smaller farms. Its overall length is 14ft, width 10ft and height 13ft 6in.

Deck Crane Installation

LAST week we attended the naming ceremony of a cargo ship designed for service in Canada on the Great Lakes. The ship, which is now being fitted out at the yard of the Atlantic Shipbuilding Company, Ltd., Newport, has been built to the order of N. M. Paterson and Sons, Ltd., Ontario, and was given the name of "Lachinedoc" by Mrs. J. Paterson, the wife of a director of the owners. Burness, Kendall and Partners were responsible for the design of the ship, which has a length overall of 259ft, a breadth moulded of 43ft 10in, a depth moulded of 22ft 6in, a deadweight of 3200 short tons on a draught of 14ft in fresh water. The salt water draught is 16ft 6in and the service speed is 8·7 knots.

A Hydroconic bow has been incorporated in the lines of the ship, this form of bow having been designed to direct the flow of water along diagonals underneath the hull and to minimise crossing of the bilge. Steering tests carried out at the N.P.L. showed that the arrangement of twin spade rudders, sited inboard of the shaft centres, and a short centre line skeg ending forward of the propellers was satisfactory in obtaining acceptable astern steering. Resistance tests also showed that the hull form compared favourably with hulls having more conventional lines.

Diesel-electric cargo cranes on M.V. "Lachinedoc"

Transverse framing has been used for the ship's sides and throughout the engine-room, while longitudinal framing has been adopted for the decks, tank top and bottom shell over the length of the parallel body. Forward of this the tank top and the outer bottom is framed diagonally on the Dioframe system, in which the longitudinals are cranked as they leave the parallel body and follow the generating lines of the Hydroconic forebody. These Dioframes, since they follow generating lines, are absolutely straight, so that there are no fairing difficulties to offset the saving in overhead welding obtained by adopting longitudinal framing. The remainder of the ship is of orthodox construction, except that the hatch coamings are continuous and the deck is raised between hatches. Pontoon hatch covers are fitted and the ship structure has been designed to give holds clear of obstruction. Equipment includes Clarke Chapman winches, Hastie steering gear for the twin spade rudders, and Port Colbourne closed fairleads. Comfortable accommodation is arranged for the officers and crew in the forecastle and poop and is panelled throughout in SaR-ReZ, produced by Saro Laminated Wood Products, Ltd., and insulated with glass wool.

Propulsion is by two Blackstone Mark E.V.S.M.G.R. supercharged engines, each having eight cylinders of 8¾in bore by 11½in stroke and rated to develop 480 b.h.p. at 600 r.p.m. Each engine drives a propeller of 7ft diameter through a Modern Wheel Drive 3 to 1 reduction gearbox. Also in the engine-room are two 100kW generators driven by Blackstone diesel engines, an arrangement which affords a high degree of standardisation.

An important departure from traditional equipment was the decision to fit diesel-electric slewing cranes, in place of the more conventional derricks, for handling cargo at ports where no shore installation is available for that purpose. Both units, shown herewith on board the ship, are Coles cranes, designed and built by Steels Engineering Products, Ltd., Sunderland, and mounted on special carriages, constructed by the shipbuilders, which are sited on transverse trucks on the raised deck between hatches. The carriages are bolted in position and can be winched over from side to side as required at any particular port.

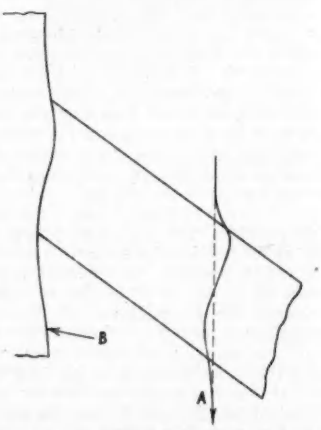
The cranes are self-contained units, one-man operated, capable of slewing through 360 deg. and powered by a Perkins P.3 diesel engine, developing 40 h.p. at 1800 r.p.m., driving a variable-voltage generator. Each crane, model F.1210c, has a steel lattice jib having 40ft centres and is placed so that it can handle the cargo from and into a hold 92ft long served by two hatches. In general the cranes will be rigged with a single-rope fall and thus rigged they have a lifting speed of 150ft per minute, while the lifting capacity ranges from 3000 lb at 40ft radius to 6000 lb at 27ft radius. These cranes are claimed to be capable of fast and precise placing of loads to which the diesel-electric transmission system employed assists by providing a fully controlled smooth flow of power. This is available at the touch of a lever and it is claimed that there are considerable economies in engine wear resulting from the fact that the driving mechanism of all motions is not kept constantly running.

The variable-voltage, shunt-wound, commutating pole generator provides power for three separate motors, one each for hoisting, slewing and derricking. These variable-voltage, series-wound, commutating pole motors have high torque/low speed characteristics and impart adequate speed to the various motions. Electro-mechanical brakes are automatically applied on hoisting, slewing and derricking motions and the gear is fully protected from sea-water, as is the control gear, which is of standard design and fitted in a specially designed watertight housing. The forward panels of the control cabin are specially strengthened to resist damage from swinging cargo, and additional removable panels are provided ready to be fitted to the cabin to give protection from spray when the cranes are stowed and the ship is on passage. During the visit one of the cranes was operated and gave a successful demonstration of cargo handling, during which various parcels of cargo were hoisted from the hold and unloaded on to the adjacent quay.

Aerodynamic Drag at Sonic Speeds

THE recent publication of the Area Rule, abstracted in our columns on September 30th (page 488), has drawn attention to the overwhelming influence of interference upon drag in a compressible flow. Experimental work has confirmed that the drag of a body depends upon the area of a section, rather than upon the shape of the boundaries of that area; the distribution of volume for minimum drag has been studied by Graham, Beane and Licher,* showing how interference drag between body and lifting element can be negative. However, while linearised compressible flow theory demonstrates that wave drag of a body of revolution moving along its axis is independent of Mach number, this is not true of a non-lifting wing.

It is not at present feasible to undertake a study of the actual flow around a body in transsonic conditions. The drag of a smooth, very slender body with wings of very low aspect ratio can be computed for supersonic speeds by a theory due to Ward,† which shows that for such a configuration the drag is independent of cross-sectional shape and depends only on the distribution of cross-sectional area. Thus this drag result has a finite and sensible value even at $M=1$, although this substitution in the functions for pressure distribution would cause them to become undefined.



Elementary example of Kuchemann's study of fluid flow, applied here to a swept wing

A study of the fluid flow was undertaken by D. Kuchemann, an elementary application of which we illustrate. Here it is postulated that the spanwise velocity of the flow along a swept wing is constant, while the component at right angles to the span varies from zero at the leading edge stagnation point to a high value over the maximum thickness.‡

The flow path indicated, *A* will be valid close to the surface, but adjoining paths will be expected to be similar. The deduction from this study is that the surface of the fuselage should conform with the flow pattern over the wing, as suggested at *B*. The fuselages that result from the Kuchemann theory have been likened to "Coca-Cola" bottles.

The same worker, in conjunction with D. E. Hartley, has extended this type of theory to supersonic flow, and this extension is the basis of the method used by the Royal Aeronautical Establishment. It is claimed that this direct approach to the problem of interference has secured improvements in performance equivalent to those resulting from the simple area rule formula.

* *Aeronautical Quarterly*, May, 1955.

† *Quarterly Journal of Mechanics and Applied Mathematics*, March, 1949.

‡ *Journal R.Ae.S.*, November, 1953.

Large Injection Moulding Machine

A NEW injection moulding machine for thermoplastic materials developed by the Projectile and Engineering Company, Ltd., of Acre Street, London, S.W.8, has a shot capacity of 160 oz and is believed to be the largest machine of its kind built outside the United States. Among the new developments of interest incorporated in this machine is a pre-plasticising unit and the "Packomatic" compensator device. The new machine can be seen in the photograph we reproduce on this page. The following table gives its leading particulars :—

Clamping force	1,041 tons
Opening force	100 tons
Closing speed	10in/sec
Opening speed	11·9in/sec
Closing time (36in stroke)	3·6 sec
Opening time (36in stroke)	3·0 sec
Platen size	60in × 60in
Mould space	60in × 35½in
Mould closing stroke	36in
Minimum mould height (with spacer)	12in
Minimum mould height (without spacer)	36in
Maximum daylight (without spacer)	72in
Ounces moulded per shot	120–180 oz
Volume moulded per shot	200–300 cu in
Plasticising capacity per hour*	250 lb
Total force on plunger	336,000 lb
Speed of injection plunger	3·55in/sec
Preplasticising transfer pressure	10,000 lb/sq in
Capacity of feed hopper	500 lb

* Subject to material and mould construction.

To facilitate transport, the machine is built in two sections, one section comprising the platen assembly, and the other the injection unit assembly. The injection unit base is of welded steel plate construction, whilst the platen assembly is mounted on a welded frame of rolled steel section. The platen frame provides support for the solid steel platens and the cast steel closing cylinder. Oil for the hydraulic system is contained in a large tank mounted directly above the mould clamping cylinder, which is gravity fed through a prefilling valve. Pipe connections pass from the hydraulic tank to a compact valve station conveniently situated at the rear of the machine so that all the valves are readily accessible. The valves are mounted on a framework which also houses the pump unit and the electric motor and starter.

The hydraulic system for the machine was supplied by Towler Brothers (Patents), Ltd., and is designed to give a maximum line pressure of 4500 lb per square inch. Mould locking is directly applied by a large hydraulic ram, and the main movement of the platen is effected at high speed on the forward and return strokes by a pair of small side rams. To prevent shock loading and mould damage, the last ½in or so of closing stroke is carried out at slow speed, by the large locking ram. In a similar manner the mould is opened slowly for about ½in then rapidly for the major part of the stroke, and finally it moves slowly again during ejection.

Means of adjustment are provided for setting the distances over which the various mould platen speeds are operative. In the case of moulds with a small overall height the mould opening and closing stroke can easily be adjusted to reduce idle time to a minimum. A 24in removable spacer is provided for the closing ram, and when it is fitted the minimum mould height is reduced from 36in to 12in.

All the platens are amply dimensioned to avoid undue deflection and ensure correct mould alignment. The thrust of the locking force is taken by four substantial steel tie bars on which the moving platen slides on four long phosphor-bronze bushes. The weight of the moving members is supported by bearing shoes mounted on the underside of the platen and running on wide, hard chromium-plated slides fixed to the machine base. To facilitate the insertion of large moulds, any one of the tie bars can be withdrawn by the removal of its split collar and nut. A special collar is provided by means of which the tie bar may be repositioned mechanically, utilising the moving platen.

The preplasticising unit fitted to the machine divides the "plasticisation" and the injection processes into two separate operations, and it is designed to give the following advantages :—

(*a*) Even temperature throughout the material, and more accurate control of temperature.

(*b*) Positive control of nozzle pressure and constancy of injection pressure at each shot.

(*c*) Close control over cavity pressure, permitting the use of the lowest necessary pressure for cavity filling, with a resultant increase in projected area at a given locking force.

(*d*) Higher rate of injection per horsepower input, due to the lower injection pressure required at the plunger.

The plasticiser is carried on a steel cradle mounted on slides fitted to a fabricated base. On this cradle, the hydraulic injection cylinder, hopper feed mechanism, preplasticising unit, injection transfer chamber and hydraulic retraction mechanism are mounted. The hopper feed mechanism is of cylindrical self-compensating construction, and it is operated by the preplasticising ram through an overload safety device. The feed plunger is hard chrome-plated against the effects of corrosion and wear. Heat transfer from the preplasticiser to the feed unit is prevented by water cooling channels around the feed aperture and in the preplasticiser plunger.

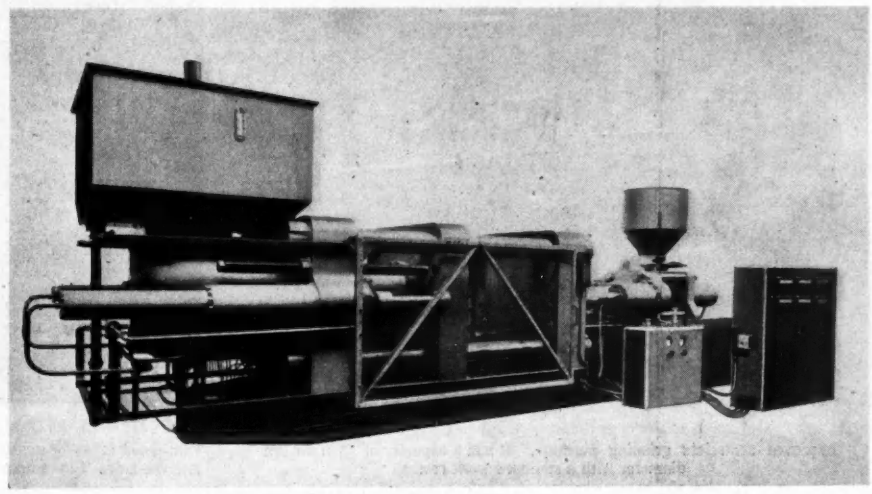
The preplasticising chamber is provided with a very high heat transfer surface per unit volume of the material, and the heating zones are carefully arranged to provide a high progressive heat transfer to the plastic material during its passage through the chamber. At the same time, the relative thermocouple positions ensure that excessive temperature and subsequent material decomposition will not occur. Heating of the preplasticiser and injection transfer chamber is effected by electric band heaters, which are controlled in a series of zones by indicating pyrometers, thus ensuring the attainment of the most satisfactory heat gradient for the material.

The material is pumped from the heating chamber into the injection chamber by the preplasticiser plunger and the nozzle in the heating chamber is designed as a plunger with a long heated passage having a small non-return valve orifice at the end. The material is pumped through this passage into the injection transfer chamber which is coaxial with the heating chamber and is fixed to a hydraulically operated crosshead. Injection into the cavity takes place with the whole heating chamber acting as a plunger and moving forward against the stationary injection transfer chamber. After the necessary holding-on period a further charge of material is pumped from the heating chamber into the injection transfer chamber, moving the whole heating chamber assembly back to its original position.

Adjustment of the injection unit to the sprue bush is effected automatically and the amount of sprue break movement is variable. Should sprue break not be required, it may be simply removed from the machine operating sequence. The hydraulic push-off cylinders which operate the sprue break can also be used to withdraw the whole injection unit from the stationary platen, thus allowing easy access to the sprue bush and nozzle for scavenging the heating unit. Four adjustable ejector rods are provided which may be used together or in pairs as required.

The "Packomatic" pressure-reducing device functions by varying the pressure input to the mould cavity, in accordance with the natural sequence of pressure changes which occur during mould filling, pressure build up, packing, discharge and cooling. A pressure balance at the gate is effectively maintained, thus ensuring the mouldings are produced under the most favourable conditions.

Hydraulic power is used for all movements of the machine, the selection of each individual movement being controlled by electrically operated pilot valves. The hydraulic unit has a total output of over 13,500 cubic inches per minute at a pressure of 4500 lb per square inch, providing a very high rate of injection and a fast mould closing speed. Separate adjustments are mounted in the hydraulic control cabinet for governing the mould clamping pressure, for accurate variation of mould cavity pressures, and for varying the injection pressure. Five process timers control the injection, injection boost, maximum pressure, preplasticiser boost and cure periods. The machine may be used with semi-automatic or hand control, the selection being made by rotation of a master switch.



Injection moulding machine with a shot capacity of 160 oz, fitted with a preplasticising unit

All the controls, together with the six pyrometers controlling the heating zones, are located in the electrical control cabinet which can be situated in any convenient position.

Push buttons are provided at the front of the machine, to control the opening and closing of the mould, advancement and retraction of the injection and preplasticising units, retraction of the nozzle and stopping the motor. To facilitate setting, additional buttons controlling mould opening and closing at "inching" speeds are fitted to the rear of the machine. These buttons are accompanied by an overriding switch which isolates control from the front of the machine, thus ensuring the safety of the setter.

GARRET WORKSHOP OF JAMES WATT.—We are informed that the contents of Watt's workshop are on view again in the Science Museum, South Kensington. They are displayed in their correct positions in a replica of the workshop incorporating the old door, window and floor-boards. Specially interesting exhibits are Watt's two sculpture-copying machines and lathe, all treadle-driven ; many small tools, plaster busts and casts ; his old leather apron and the travelling trunk containing the school books of his younger son, Gregory Watt. The garret workshop was on the second floor at Heathfield, the house near Birmingham built by Watt in 1790, where he lived till his death in 1819. He used the workshop during his retirement from 1800 onwards for many experiments but not for the development of the steam engine, which he did twenty-five years previously in Boulton's factory at Soho.

Centreless Grinding Machine

AN improved design of the firm's No. 2 centreless grinding machine recently introduced by Cincinnati Milling Machines, Ltd., Tyburn, Birmingham, 24, has a capacity from $\frac{1}{16}$in to 3in diameter with a standard work rest and 2in to 4¾in diameter with a low throughfeed work rest. It is built for use with 4in, 6in or 8in wide grinding wheels, 20in maximum and 14in minimum diameter, and regulating wheels of similar widths from 12in to 9½in diameter.

The grinding wheel spindle is mounted on "Filmatic" bearings and is driven by a 15 h.p. motor. The regulating wheel is driven by a 1½ h.p. motor through a back gear and a wide vee-belt. This vee belt runs on variable pitch sheaves which are adjusted by a handwheel with reference to a tachometer, and this drive gives two steplessly variable speed ranges from 13 r.p.m. to 78 r.p.m. and 68 r.p.m. to 392 r.p.m.

The general arrangement of the new machine can be seen in the photograph we reproduce. As in the previous design of No. 2 machine a lower slide, mounted on bedways at right angles to the grinding wheel spindle, carries an upper slide assembly on which the regulating wheel is mounted. With this arrangement the work rest mounted on the lower slide can readily be positioned in correct relationship to the two wheels when necessary. The complete slide assembly can be swivelled slightly on the bed to compensate for small errors in truing or set-up. The upper slide and lower slide are rigidly locked together for operation as a single unit. The lower slide is actuated by a stabilised infeed screw and moves on preloaded ball bearings which eliminate "stick slip" and enable very accurate infeed adjustments to be made.

To prevent vibration and its resultant chatter on workpieces, an automatic means of balancing the grinding wheel mounting is provided. For this balancing operation the operator simply unclamps the mechanism by a small lever and watches a vibration gauge dial. When the needle of the dial stops oscillating the wheel is in balance and the clamping lever is relocked. Profile truing equipment fitted for the grinding wheel is operated by a hydraulic motor through two controls. One control is a small lever which engages rapid and truing rates and change of direction of traverse, and the other is a graduated knob which changes the rate of traverse. Micrometric adjustment is provided for the truing slide.

A large graduated infeed wheel on the upper slide on the front of the machine is used for size adjustment and positioning the slides when setting up; when engaged in infeed grinding the operator uses the lever to be seen in the horizontal position below the wheel in the illustration. The machine is normally fitted with hand-screw-operated truing mechanism for the regulating wheel, but power-operated gear can be fitted if specified.

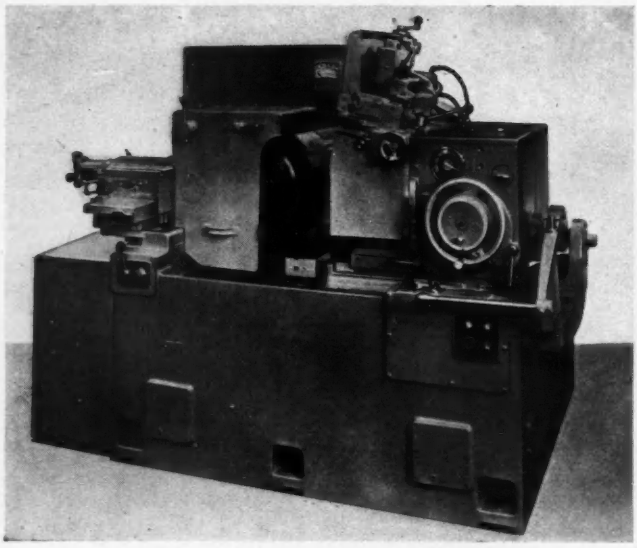
Automatic lubrication for the grinding and regulating wheel spindle bearings is supplied from the central hydraulic system, and the bearings within the slides are lubricated from a one-shot system. Coolant is supplied from a 65-gallon tank by a motor-driven pump at a rate of 30 gallons a minute. The standard fixtures and attachments available for the machine include various work rests, long bar grinding attachments, automatic infeed attachments, and automatic feed hoppers.

Two-Speed Drive For Textile Spinning Frames

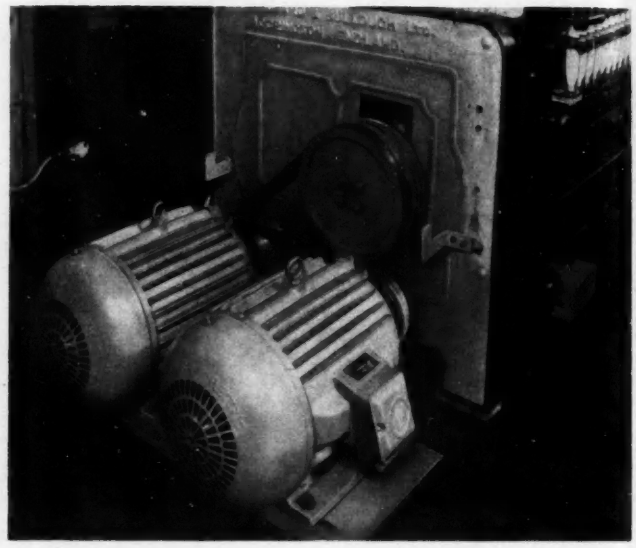
A SIMPLE method of driving textile ring spinning frames using two identical electric motors has been developed by the English Electric Company, Ltd., Queens House, Kingsway, London, W.C.2. It is known as the "two-speed drive" and is designed to ensure an overall low end-breakage rate, with improved production and quality of yarn. It has been installed on ring frames spinning up to 90's counts and can be fitted to all makes of new and existing ring spinning frames.

It will be appreciated that for many years the textile industry has been concerned with the problems of obtaining the highest possible production of cotton yarn with consistent quality. The older form of spinning, the Lancashire mule, gave a constant tension spin, although the spinning cycle was itself intermittent. Yarn production of the mule, however, was found to be less per unit of floor area than that of the ring spinning frame, which eventually superseded the mule. The ring spinning frame was designed to give a higher yarn production as well as a continuous spin. Its main disadvantage is that, when driven at a constant speed, the yarn tension varies throughout the spinning period. Yarn tension depends upon the diameter of the yarn package, or cop, on the spindle at the point at which it is wound on, and also varies cyclically with the ring rail position. This variable tension creates thin places along the length of the yarn, which is known as "yarn irregularity." Yarn tension is greatest when being wound on to the smallest diameter of the conical build of the cop, and is least when approaching the maximum cop diameter; the end-breakage rate is greater at the bottom of the package at the start of spin, and also at the nose or end of spin, than it is for the central body of the cop.

In the new two-speed drive two identical squirrel-cage induction motors are connected together by vee belts and pulleys, one pulley being slightly larger in diameter than the other. A drive is taken from the smaller pulley to the "tin roller" shaft of the ring spinning frame. When the motor with the smaller pulley is energised the frame runs at a lower speed than when the motor with the larger pulley is energised and thus two driving speeds are available. The actual changes of speed are arranged to take place when the bottom of the cop has been built and at the nose of the cop, the speed changes being from "low" to "high" and then to "low." These speed changes are affected by a cam-operated switch attached by a flexible shaft to the ratchet wheel shaft of the builder motion of the frame. The switch is arranged to operate either of two main contactors electrically, the contactors being mechanically interlocked so that both cannot be "in" together. For frames fitted with an electro-mechanical brake to prevent snarles in the yarn when coming to a standstill, a third contactor is provided, which operates before either motor is energised. Changes of setting for the speed-change switch are simple and can be accurately made with the aid of a screwdriver. As illustrated here the motors are totally enclosed fan-cooled machines and comply with British Standard dimensions.



Improved centreless grinding machine. It has a capacity of $\frac{1}{16}$in to 3in diameter with a standard work rest.



Two-speed drive for a ring spinning frame, with guard removed to show pulleys and vee-belts. The motors are identical, each being rated at 10 h.p. at 1455 r.p.m.

Photographic Recorder For Documents

To provide an economical method of recording documents and drawings a new photographic recorder, known as the "Statfile" model 70mm, has been introduced by Photostat Ltd., 1–2, Beech Street, London, E.C.1. The equipment comprises a camera, camera trolley, track chassis, easel and lighting for recording and projection on to photographic sensitised materials.

The camera is fitted with a film magazine, which can be loaded with a 100ft long spool of 70mm film—sufficient to provide 300 exposures on a complete length, or shorter lengths can be cut off if required. The magazine is fitted with an electric motor, which moves the film after each exposure is made. When the control button is pressed the camera shutter is opened for the required exposure, after which the film is automatically wound down. This operation can be carried out either from the main control panel on the camera trolley or from a sub-panel at the side of the easel, so making it unnecessary for the operator to leave the easel when loading and unloading drawings and sensitised materials. The recorder is accurately calibrated to eliminate any necessity for visual focusing.

Alternative arrangements are provided in the

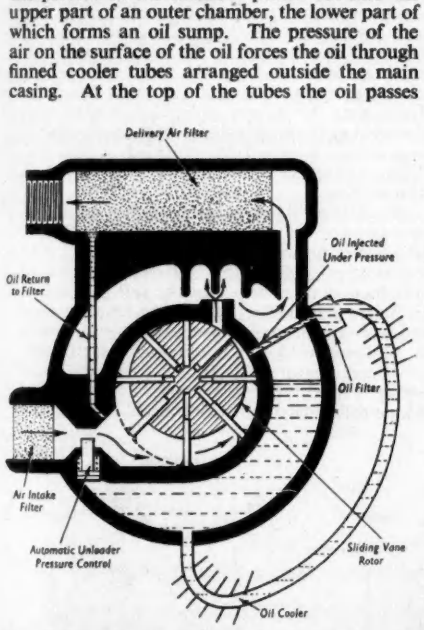
equipment for projecting from a film, either in roll form or from single-sheet negatives, on to sensitised materials. The projector used comprises a triple condenser lens assembly with a 6V 30W projection lamp.

An "Apotal" f/9 6in lens fitted to the camera gives a maximum reduction ratio of 17 : 1, and this allows 70mm negatives to be made from originals up to 40in by 60in in size. The quality of the projection system is stated to be such that when a negative is enlarged back to its original size very high-quality definition is obtained. Each recorder is equipped with two synchronous timers and a magnetic counter for registering the number of exposures. Two models of the recorder are available; one has a 40in by 60in easel and the other a 34in by 55in easel. The maker points out that the new recorder is intended primarily for mass recording of large numbers of drawings, and for the normal work of an industrial concern its earlier design of half-plate model 3 recorder is the more suitable apparatus.

Mobile Rotary Compressors

It is announced by the Hymatic Engineering Company, Ltd., Redditch, that a new range of air compressors working on the firm's "Hydrovane" principle has been introduced to replace the existing range of reciprocating mobile compressors. The new machines are made in ten motor-driven sizes with working pressures from 45 lb to 100 lb per square inch and displacements from 7 to 40 cubic feet per minute; and in five petrol-engine-driven sizes with working pressures ranging from 45 lb to 100 lb per square inch and displacements from 7 to 23 cubic feet per minute.

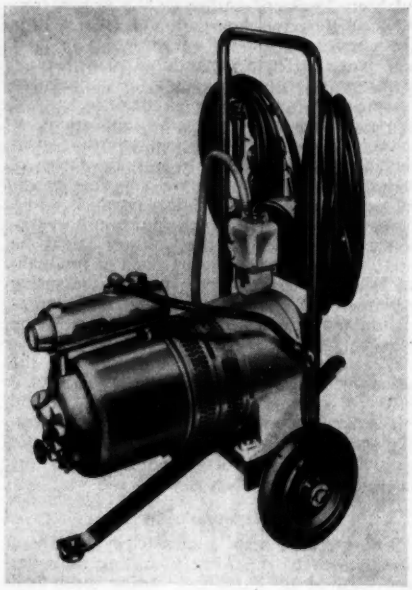
The principle upon which the "Hydrovane" compressor operates can be seen in the diagram we reproduce herewith. A slotted rotor with sliding vanes rotates in an inner chamber through which filtered oil is circulated at a high rate to seal, cool and lubricate the moving parts. Air compressed in the chamber passes out into the upper part of an outer chamber, the lower part of which forms an oil sump. The pressure of the air on the surface of the oil forces the oil through finned cooler tubes arranged outside the main casing. At the top of the tubes the oil passes



Schematic diagram showing the construction and operation of the "Hydrovane" rotary compressor

through a filter and then into a pipe leading to the rotor chamber.

As the compressed air leaves the rotor chamber it impinges on a plate, and this has the effect of removing part of the oil suspended in the air. The upper part of the pressure chamber forms a delivery port for the compressed air and it is fitted with a felt filter which serves to remove the remainder of the oil suspended in the air. Oil from the delivery filter is piped back to the intake side of the compressor for recirculation. The oil separation takes place while the air is still at a temperature above its dewpoint, so water vapour cannot condense and be returned to the sump with the oil.



Typical motor-driven mobile rotary compressor

Automatic pressure control is provided by a suction unloader operated on the servo principle by the oil under pressure in the sump. A hand control can be adjusted to give delivery at any pressure, irrespective of flow, the compressor pumping only sufficient air to replace that being used. The compressor delivers air smoothly without pulsations and the makers point out that no air receiver is required with these machines.

A typical model of one of the new motor-driven compressors is also illustrated and shows the compact arrangement on a tubular steel trolley. This machine is fitted with a 1½ h.p. motor and has a displacement of 9 cubic feet per minute at 60 lb per square inch.

Spoil Elevating and Loading Attachment for a Motor Grader

The scope of the "Super 12" motor grader made by Blaw Knox, Ltd., 90–94, Brompton Road, London, S.W.3, has been considerably widened by the introduction of a new elevating attachment. This elevator can be used to load spoil into dumpers or discharge it 25ft away from the side of the machine, as it moves along; it enables the machine to be used for road building, widening and maintenance, loading, ditching, terracing and a number of other duties involving earth moving. A grader with one of the new elevators can be seen in operation in the photograph reproduced below, where it is loading loose sandy soil into a tipping wagon at a rate of some 600 cubic yards an hour. It is stated that it can normally load, dependent on the type and condition of the soil, from 400 to 750 cubic yards an hour, or cast from 700 to 1500 cubic yards of soil an hour.

The elevator consists of a 42in wide belt conveyor carried by a rigid frame of rolled steel sections with tubular cross bracings, and pivotally supported at the lower end by a frame fixed to the grader chassis. The basic length of the conveyor is 15ft and extension sections 3ft, 5ft and 10ft long can be fitted to provide lengths of 18ft, 20ft, 23ft and 25ft. The outer end of the conveyor frame is supported through steel cables on a power-driven drum, and these cables are used for adjusting the discharge height of the conveyor.

The conveyor belt is supported on idler rollers spaced at 1ft intervals along the frame, and runs between a 14in diameter head pulley having a crowned face for belt alignment and a 6½in diameter tail pulley. Both of these pulleys are keyed on shafts running in ball bearings and the bearings of the head pulley are mounted on steel slipper plates fitted with screwed tension rods. A scraper cleaning device is fitted on the tail pulley.

A 30in diameter plough disc which is set at an angle to feed spoil on to the belt is carried by a heavy box-section member attached to the front end of the grader main frame. This disc, of heat-treated carbon-manganese steel, can be rotated on the mounting and locked to present a new face when wear has taken place on one part of its circumference.

Power for driving the conveyor is taken through vee belts from a pulley on the engine crankshaft to a 9in diameter twin dry plate clutch mounted in ball bearing plummer blocks on the frame of the grader at the side of the radiator. The clutch has a rated transmission capacity of 52 b.h.p. and the drive is transmitted from it through two reduction gearboxes connected by telescopic shafts fitted with Hardy-Spicer universal couplings. One of these reduction boxes is fitted under the cab of the machine and the other at the head pulley. Drive from the second reduction gearbox to the conveyor head pulley shaft is transmitted through flexible couplings.

When a grader fitted with the elevating attachment is required for normal duties the main parts of the attachment can be removed in a few hours, leaving a few mountings which do not interfere in any way with the grading operations.

Pressure Gear Oils.—The Chemical Inspectorate of the Ministry of Supply has issued a new specification, C.S.2758, for extreme pressure gear oils for the Services. This specification requires performance testing of gear oils; copies may be obtained from The Director of Chemical Inspection, Station Approach Buildings, Kidbrooke, London, S.E.3, while inquiries relating to the approval of oils should be made to Chemist in Charge, Chemical Inspectorate, 12/14, Tavistock Street, London, W.C.2.

Motor grader with 25ft elevating attachment, loading loose sandy soil into a 12-cubic-yard tipping wagon at a rate of more than 600 cubic yards per hour

Instrumentation of a 14in Experimental Rolling Mill*

By S. S. CARLISLE, M.Sc., A.M.I.E.E.† and G. W. ALDERTON, B.Sc.‡

This paper describes the comprehensive instrumentation on the new 14in experimental rolling mill in the British Iron and Steel Research Association (B.I.S.R.A.) Sheffield Laboratories. Roll force on each side of the mill, front and back tensions and strip gauge, using the B.I.S.R.A. gaugemeter principle, are continuously indicated on high-speed servo-operated potentiometric indicators fitted with large pointers and dials. The whole instrumentation scheme is designed and laid out as a model system for industrial mills of this class. Facilities are provided for experiments with various systems of automatic gauge control. A simple system of on/off control of the existing a.c. screw motors according to the gauge deviation has been successfully operated with a tolerance of only +0·0005in. Facilities are also provided for switching to automatic tension control based on measured tensions as an alternative to the present method of control of coiler-motor current with correction for radius of build-up.

THIS mill has been installed in the Sheffield laboratories of B.I.S.R.A. to facilitate research into cold rolling at high speeds and in particular for experiments with new systems of automatic gauge control. It is briefly described as a 14in four-high reversible mill equipped with coilers by which front and back tension can be applied (Fig. 1). The system of four rolls (four high) is used so that small-diameter rolls can be employed to roll thin strip efficiently, and the stiffness necessary to prevent roll bending is provided by the large-diameter back-up rolls. The force applied to the rolls, and hence the reduction in gauge effected by a pass through the mill, is controlled by the motor-driven screws which apply the downward force on the roll bearings. The coilers and uncoilers on each side of the mill

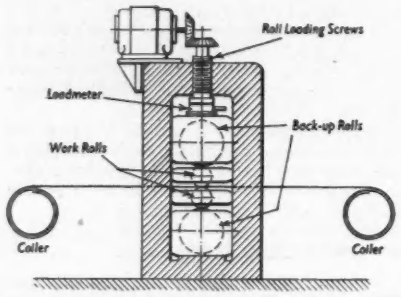


Fig. 1—Arrangement of the 14in four-high reversible cold rolling mill

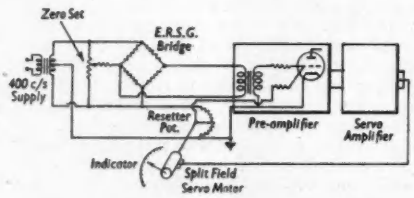
are provided with adequate power so that appreciable tension can be set up in the strip on both sides of the mill. This is done because both front and back strip tension affect the rolling process. Since it is necessary that the maximum tension allowed—5 tons in this case—be provided right up to maximum mill speed, it is clear that the coiler motors must have a very high power rating. The mill is designed to operate at strip speeds of up to 2000ft per minute. To provide constant tension during an experiment it is necessary that the coiler torques be automatically corrected for build-up of strip on the coilers, which alters the effective radius. The control equipment and the mill drives are arranged so that it can roll strip in either direction. This feature greatly facilitates the use of the mill for experimental purposes and is representative of a large number of mills operating in industry.

The essential variables in the rolling process are roll force (applied on each side of the mill by the screws), strip tension both front and back, strip gauge on leaving the mill and the driving torque at the mill rolls. It is necessary that the majority of these variables should be indicated and recorded to facilitate operation of the mill and research into rolling processes. Methods had been developed earlier by the British Iron and Steel Research Association (B.I.S.R.A.) for measurement of roll force,[2] strip tension[3] and strip gauge.[1] These methods all made use of electric resistance strain gauges for the primary measurement, but a variety of circuit techniques were employed according to the application. It was decided to use these principles in the instrumentation of this mill, but to unify the design of the instrumentation system and introduce circuit techniques and methods of display which would act as a model upon which future mill instrumentation schemes in the industry might be based. Special attention was given to rationalisation of the design of the various measuring systems to facilitate their commercial reproduction and to make easier the proper servicing of the equipment.

The electronic apparatus employed with the measuring systems also provides the basis of a variety of systems of automatic gauge control. One system of control has already been successfully operated, using the gauge indicating pointer to provide on/off control of the mill screw motors via their existing contactors.

BASIC MEASURING SYSTEM

During recent years a satisfactory system of measurement of roll force in rolling mills has been evolved by B.I.S.R.A.[2] using steel load cylinders fitted with electric resistance strain gauges and located under the mill screws. The B.I.S.R.A. gaugemeter[1] also employs these load cylinders. The method of measurement of strip tension, either by torque measurement in the coiler shafts with suitable correction for coil



E.R.S.G. denotes electrical resistance strain gauge.

Fig. 2—Schematic of potentiometer indicator system

radius build-up,[3] or by a three-roller system over which the strip is passed,[4] is also basically dependent on electrical resistance-strain-gauge bridges.

Since a strain-gauge bridge forms the source of the measuring signal in all three measurements, it was decided to evolve a circuit technique and system of amplifiers which would be generally applicable. The basic circuit technique chosen is shown in Fig. 2. It employs a well-known automatic potentiometric system of indication in which the output signal from the bridge is compared with a signal generated by a linear potentiometer, and any difference signal is amplified and used to drive a servo motor coupled to this resetting potentiometer. The system thus operates until a condition of balance is achieved in which the angular position of the resetting potentiometer is a continuous measure of the magnitude of the unbalance of the resistance-strain-gauge bridge. The following features of the system are noteworthy :

(*a*) The use of a self-balancing potentiometric system of indication makes the calibration independent of the gain of the electronic amplifiers employed. This contributes to reliable operation, easier installation and initial adjustment, and simplifies servicing. Furthermore, a mechanical drive of appreciable power is available to operate a large and easily read pointer. This feature is particularly advantageous for industrial instrument displays.

(*b*) The bridge is excited from a 400 c/s source. This a.c. excitation permits the use of straightforward electronic amplifiers and avoids the many problems introduced in the amplification of low-level d.c. signals. Also any errors due to thermal e.m.f.s such as might arise with a d.c. circuit technique working at very low signal levels are avoided. The frequency of 400 c/s has been chosen as a carrier in preference to 50 c/s in order to provide the quick-response system which will ultimately be required in certain systems of automatic gauge control. This higher frequency has also the advantage that discrimination against 50 c/s pick-up is easily provided. It is also an accepted standard for a very wide range of servo mechanisms, and already a large number of servo amplifiers designed to work on this frequency are available and can be directly employed in this measurement system.

(*c*) The centre point of the bridge supply transformer is earthed, and, by placing an earthed screen round the bridge-output connecting wires, leakage currents across the bridge arms, which might cause unbalance, can be prevented. This technique of guarding is particularly desirable for high-resistance bridge circuits, but is only an added precaution for the low-resistance foil gauges actually used in this system.

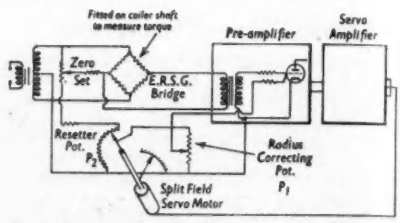
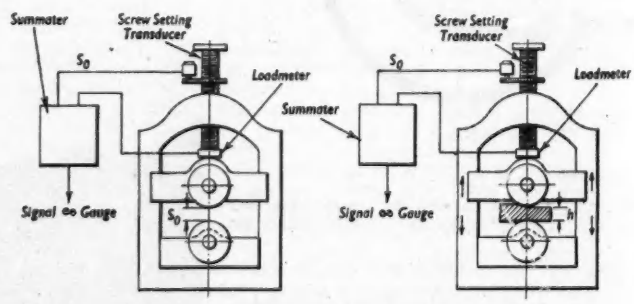


Fig. 3—Basic circuit of strip tension measuring systems

Roll-Force and Tension Measurement.—The circuit shown in Fig. 2 includes the essentials of the roll-force measuring system. For tension measurement, the method using coiler-shaft torque suitably corrected for coil radius has been employed. The basic circuit is shown in Fig. 3. The voltage from the resetting potentiometer is attenuated by the potentiometer P_1 according to the radius of the coil. It can be shown that the pointer indication is thus proportional to the output signal from the resistance strain-gauge torque bridge divided by the coil radius. Thus the indication is proportional to strip tension.

Strip-Gauge Measurement.—For continuous measurement of strip gauge the B.I.S.R.A. gaugemeter principle[1] has been employed. The operating principle of this instrument is that the introduction of a strip into the roll gap causes an elastic deformation of the mill housing, rolls and screws, and thus a continuous measurement of roll force will give a continuous indication of variations in strip gauge, provided that the screw setting is fixed. Hence by combining the signal from a roll-force meter with a signal representing screw setting, an absolute measure of strip gauge can be made, unaffected by variations in the screw setting. Fig. 4 shows the principle. Suppose that the setting of the screw is such that there is a gap S_0 between the rolls with the mill



S_0 gap between rolls with no strip present.
h = Exit gauge = Original gap S_0 plus amount of stretch of mill housing and compression of rolls.

Fig. 4—Principle of the gaugemeter

* Abstract. Institution of Electrical Engineers (Measurements and Control Section). London, December 6, 1955.

† South Wales Laboratories of the British Iron and Steel Research Association.

‡ British Iron and Steel Research Association Metal Working Laboratories.

unloaded. When the mill is loaded by strip between the rolls, a roll force F is generated, and if the coefficient of elasticity of the mill housing and rolls is M, the gap between the rolls will increase by F/M owing to the presence of the strip. If the strip exit gauge is h

$$h = S_0 + \frac{F}{M}.$$

Thus it is only necessary to add together a signal proportional to S_0, which can be generated by a suitable transducer operated from the mill screws, and a signal from the roll-force meter, which is proportional to F. The constants of the screw-setting transducer and the roll-force loadmeters must be matched so that their output signals are in the correct ratio for the mill elastic coefficient M. The basic circuit technique used is shown in Fig. 5. Again a.c. excitation has been used in order to unify the electronic equipment required.

A signal proportional to roll force is provided in the usual manner and fed to the pre-amplifier via a step-up transformer, as in the circuits described earlier.

The gauge meter is designed so that the indicator shows only the deviation in gauge about a nominal value which can be set on control knobs. This is done by using a double-decade potentiometer P_2 connected in parallel with potentiometer P_1, the screw transducer. The mechanical drive from the mill screw to potentiometer P_1 can be matched to the resistance steps of the double-decade potentiometer P_2 so that each step of P_2 corresponds to a certain change in screw setting measured in thousandths of an inch.

A signal corresponding to the deviation in gauge about the set nominal value is obtained by adding the voltage difference $(V_1 - V_2)$ to the roll force signal determining the stretch of the mill housing. This summation is done in the pre-amplifier by the resistors R_1 and R_2. As in the previous circuits, this resultant signal is measured by balancing it against a signal from a resetting potentiometer added in through summating resistor R_3. When the resetting potentiometer has been driven to a position of balance its indication represents gauge deviation about the nominal value set on the double-decade potentiometer P_2.

In the design of this circuit particular attention has to be given to the transformer T_1, so that its secondary voltages are maintained accurately in phase with each other for the particular loads applied to the windings. Also the transformer T_2 and circuit of the resetting potentiometer have to be designed to minimise phase shift, so that

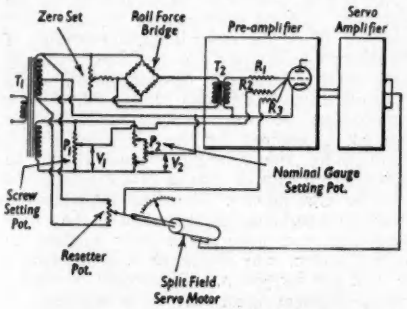


Fig. 5—Basic circuit of a.c. gaugemeter system

the three voltages summated in R_1, R_2 and R_3 are held accurately in phase.

The circuit shown in Fig. 5 is much simplified and does not show adjusting and calibrating controls.

Amplifiers and Control Units.—The circuits of the pre-amplifiers and servo amplifiers employed in the systems described for roll force, strip tension and gauge measurement are almost identical, their only individuality being in the voltage gain required to accommodate the different levels of input signal and in the gauge meter pre-amplifier, where three summating resistors are used instead of two.

Beside the units so far mentioned, another termed a "control unit" is introduced, whose function is to accommodate the zero setting and calibration controls and the transformer for supplying the appropriate resistance strain gauge bridge in each measuring system. The control unit also serves as a junction unit to permit a good wiring layout.

The general arrangement of the instrumentation scheme is shown in Fig. 6. The arrangement of the roll force and tension measuring systems will be clear from previous discussion. The control units for these measurements are built as two-channel units. The gauge meter control unit, in addition to housing the necessary zero setting and calibration controls, also includes the screw setting potentiometer with its servo-control desk. It also includes relays required in the automatic control systems described later.

On the main control desk is fitted the nominal gauge setting control and a push button to actuate the automatic zero-set mechanism. Also fitted on this part of the control desk is a change-over switch to introduce automatic gauge control.

The cable runs between the electronic unit and other parts of the system are approximately 50 yards long. The only leads which have been screened are the output leads from the roll force and coiler torque measuring bridges. The need for screening has been largely eliminated by

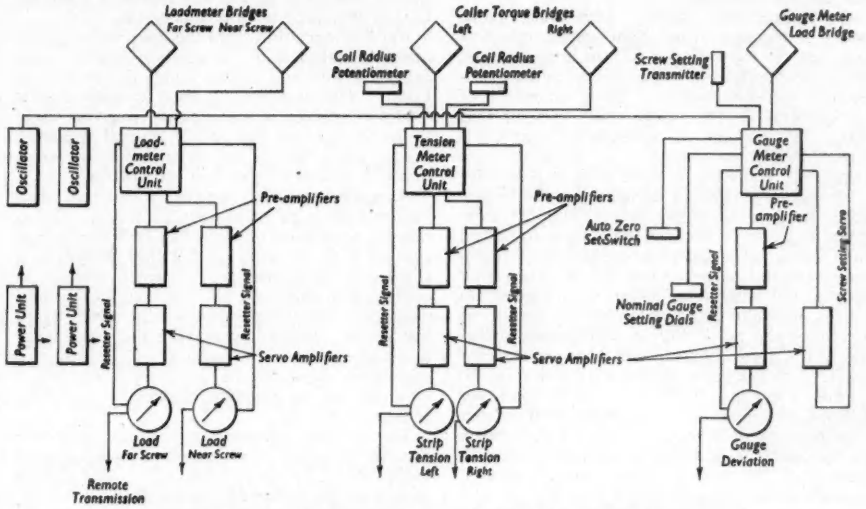


Fig. 6—General arrangement of the five-channel instrumentation system

motor drive which is operated from a Magslip transmitted on the mill housing. This remote control of the screw potentiometer by a Magslip system simplifies the fittings on the mill housing and locates the potentiometer in a more accessible position for servicing. The gauge meter control unit also includes an automatic zero setting mechanism, the operation of which is facilitated by the use of a servo drive to the screw potentiometer. Fig. 6 shows how the whole instrumentation system lends itself to standardisation of the electronic apparatus employed.

There are five pre-amplifiers, six servo amplifiers and three control units, two oscillator units to supply the 400 c/s power supply and two power units to provide the necessary d.c. supply for the whole equipment. In addition, a switching unit has been included to centralise the switching control of the apparatus.

All the electronic equipment is contained in a multi-unit rack, which was designed to house servo amplifiers in a complex system of electronic servo mechanisms designed for the Admiralty; it has been found very useful in this application to a multi-channel mill instrumentation scheme. The individual electronic units fit into this rack and make contact via plugs and sockets. The servo amplifier units are built on trays, 3in wide by 8in high and 17in long, and are of a type now being produced in large quantities. The oscillators, pre-amplifiers and load- and tension-meter control units are built on to trays identical with those on which the servo amplifiers are assembled. The power units and gauge meter control unit are built on heavier sliding trays which occupy the space of three amplifier trays.

[The authors then gave a detailed description of the preamplifiers, servo-amplifier, oscillator, power pack, loadmeter control unit, torsion-meter control unit, gaugemeter control unit and the potentiometric indication units.]

General Arrangement of the Instrumentation System.—All the electronic units and the control units are mounted in the rack, which can accommodate thirty-six units, each of 3in width. Altogether thirty spaces are used, including those for a spare pre-amplifier, servo amplifier and oscillator. The rack has a terminal compartment which acts as a central junction box for the whole system. Into it are wired all the connections from the five-channel indicator unit on the mill housing, from the various measuring elements and from the control elements on the main mill careful grouping of all the cables and cores so that the inductance of low signal level circuits is small.

Performance of the Measuring System

The performance of the system is judged on its accuracy, the presentation of the measurement and the speed of response of the indicator. The latter two are determined by the design of the automatic potentiometer system. The automatic potentiometer is also one factor determining the overall accuracy of the measuring system, and since it is common to each measurement its properties will be considered first, followed by a discussion of the limitations of accuracy which are peculiar to the measurement of roll force, strip tension and gauge.

Automatic Potentiometer.—The accuracy of the automatic potentiometer display depends basically on the linearity of the potentiometer winding itself, which has a specific linear accuracy of 0·1 per cent. The fixed resistors in the potential dividers of the control units and in the summating circuit of the pre-amplifier affect the calibration, so that their stability affects the accuracy of the system. These resistors can be relied upon to maintain their values to within 0·1 per cent. The loop gain of the servo mechanism is sufficiently high to ensure that the motor will turn for an unbalance of 0·1 per cent of the full-scale deflection. The a.c. and d.c. amplifier gains are chosen so that the drift of the d.c. stages in the servo amplifier produce negligible error. In all, an accuracy of 0·2 per cent is expected from the automatic potentiometer.

The clarity of presentation of the measurement given by the large pointer and dial is an important advantage which may often justify the use of an automatic potentiometer even when its high accuracy is not called for. It is of vital importance in an industrial installation and encourages plant operators to make the fullest use of their instruments. It has already been observed that in this new experimental mill much more attention is paid to the instrument readings in normal rolling than was the case with other experimental mills equipped with small moving coil indicating meters.

The speed of response is approximately 0·3 second for full-scale deflection, which is adequate for visual observation.

Load Meters.—The accuracy of the roll force measurement depends primarily on the "load

cell" and its strain gauges. There are three main sources of error :

(*a*) Stress distribution in the cylinder.—There is some departure from linearity in the relations between roll force and surface strain because the distribution of stress over the cross-section of the cylinder varies slightly with the roll force. The relation may also be influenced by off-axial loading on the cylinder, so that care must be taken when calibrating the load meter to ensure that the conditions of application of the load are the same as when it is in use. Errors from these sources may amount to as much as 0·8 per cent with the present load cells, but it is thought that this can be improved.

(*b*) Temperature Effects.—The strain gauge bridge is formed from eight gauge elements mounted on the cylinder surface and arranged to measure both axial (compressive) and circumferential (tensile) strains. The arrangement of the elements in the bridge arms is such that effects of changes in temperature are compensated, if it is assumed that all gauges are identical. There is, however, still a possibility of temperature changes unbalancing the bridge, either because of temperature differences from gauge to gauge or because the gauges do not all have the same temperature coefficient of resistance. The foil gauge has been found to be rather poor in the latter respect, but with wire strain gauges, carefully arranged on the cylinder so as to reduce the possibility of temperature differences, the zero changes with heating are very small. The change with uniform heating of the cylinder is less than 0·02 per cent of full scale per degree Centigrade. It has also been observed that a temperature difference of 5 deg. Cent. between points just above and below the gauges, owing to heating of the cylinder from the roll chocks, caused a zero change of only 0·2 per cent.

(*c*) Creep in the Gauge Adhesive.—Creep in the gauge adhesive is a well-known phenomenon in strain gauge work, but when using the modern thermosetting resins its effect is small and amounts only to 0·2 per cent in an extreme case. There is also a limit to the accuracy of calibration. The load meters were calibrated against a substandard strain gauge load cell which had been calibrated against the national standard. The national standard for forces above 50 tons is a parallel combination of strain gauge load cells, each of which has been calibrated against the 50-ton standard deadweight machine.

The accuracy of the standard is given as 0·25 per cent and the substandard is considered to have been accurate to 0·5 per cent. The overall accuracy of the experimental mill load meter is taken to be ±1 per cent and the reproducibility better than ±½ per cent.

Tension Meters.—The tension meters, which are basically dependent on shaft torque measurement using resistance strain gauge elements, are limited in accuracy by the same sort of factors as the load meters. They were calibrated against a proving ring previously calibrated against a deadweight machine, the accuracy of the calibration being ±½ per cent. As constructed, the accuracy of the tension meter is also limited by the radius factor potentiometer, which introduces an error of 2 per cent because of its high resistance. When this is changed the overall accuracy will be better than ± 1 per cent.

The Gauge Meter.—It was assumed, when describing the principle of the gauge meter, that the gap between the mill rolls, and hence the strip thickness, was related to the screw setting S and to the roll separating force F according to the linear relation $h=S+F/M$. In fact, this is not exactly true, and the deviations from it are the main cause of inaccuracy in the gauge meter.

The most important of these errors which arise in the rolling mill itself is that due to thermal expansion of the mill rolls. Despite water cooling, the rolls become hotter than the mill frame and the resultant differential expansion causes a change in the roll gap which is not included in the measurement. In effect, there is an error in the measurement of the screw setting S, its magnitude being approximately 0·0003in per deg. Cent. roll temperature change. A zero check of the gaugemeter, as described earlier, can be employed at intervals to correct the error, so that the maximum error depends on the frequency of the zero checks in relation to the rate of temperature change. It is impossible to carry out a zero check when strip is in the mill, so that the maximum frequency is one for each coil of strip. The magnitude of the error thus depends in a rather complicated way on the particular circumstances—the type of mill and the work it is doing, the efficiency of the roll cooling and the size of the coil, and so on. Trials of a gaugemeter system on a large hot mill showed that expansion is not then a serious source of error, but for precise work on the experimental mill it is thought that it will sometimes be necessary to provide means of checking the gaugemeter more frequently, whilst the strip is in the mill, by comparison against some other gauge. An investigation into means of reducing the roll expansion error is in progress.

Another deviation from the theoretical gaugemeter equation is in the relation between mill extension and roll force, which is not strictly linear. The curvature is marked only at low values of roll force, but it exists over the whole range. It is found that for the normal operating range, above 50-ton roll force, the error introduced in this way is less than ±0·0005in.

A small correction has to be applied when narrow strip is rolled at high roll loads. This is due to indentation of the rolls where they are in contact with the strip, so that they deform in a slightly different manner from when they are in contact with each other. This results in a slight change of the mill elastic constant which again introduces an error by making the gaugemeter equation incorrect. Instead of applying a correction, it would be possible to provide a control to set the gaugemeter constants according to the strip width.

The present gaugemeter will not give the average thickness of strip with a wedge-shaped cross section. It will, in fact, either read slightly more than the thicker edge or less than the thinner one, because it measures the roll gap under one screw only. This error, which may be of the order of 0·001in, can be completely eliminated by taking the mean of the roll gap under the two screws, i.e. the mean of the roll force and the mean screw motion. A simple modification to do this is being made. Two load bridges, one on each side of the mill, will be connected in parallel to give the mean roll force. A follow-through Magslip transmitter on the second screw will, in conjunction with the existing transmitter, give the sum of the two screw motions. This can be halved, thus producing the mean, by altering the gearing in the gaugemeter control circuit by a factor of two.

The pure instrumental errors are, in general, negligible compared with those just described which originate in the mill itself. The mill-screw follow-up servo-mechanism, the potentiometer it drives and the remainder of the gaugemeter electrical system have been designed to have a static accuracy of 0·0001in. The only other significant source of error is the loadmeter ; although its absolute accuracy is of no consequence in this matter, good linearity and reproducibility are essential. As the elastic constant of the experimental mill is about 3000 tons per inch an error of 1·5 tons (1 per cent of full scale) in each loadmeter would result in a gaugemeter error of 0·001in. The maximum error expected from this cause is 0·0005in.

It is concluded that, apart from the thermal-expansion error, the nature of which is discussed fully above, the gaugemeter is accurate to the order of ±0·001in. This is with the restrictions that the roll force must be above the 50-ton minimum (below which the mill-extension/roll-force relation departs appreciably from the linear) and that a correction is made if the width of the strip rolled is changed.

On some industrial mills where rolling schedules are such that the roll temperature changes would cause unacceptable errors, it may be necessary to use another gauge-measuring system, such as a flying micrometer or X-ray gauge, to monitor and apply correction to the gaugemeter. Such a procedure would be justified for many automatic gauge control installations where the high speed of response, which only the gaugemeter system can give, may be essential.

Automatic Gauge Control

The instrumentation system has been designed to provide facilities for experiments with a variety of automatic gauge control systems. Already a simple method of on/off gauge control has been applied using the gauge error indicator to provide the control action.

Automatic On/Off Gauge Control.—In the indicator unit a pair of cams is fixed to the pointer shaft and arranged so as to operate one or other of a pair of microswitches if the gauge deviates by more than a set tolerance from the nominal value on the gauge setting control. This tolerance zone can be varied by altering the cam settings. When switched to automatic gauge control, these microswitches actuate relays located in the electronic rack, which in turn energise the appropriate screw motor contactor, thus raising or lowering the screws to provide the necessary correction to the gauge.

The screw drives are provided by a.c. induction motors, and in order to provide quick braking and to minimise overshoot when the control contactors are open-circuited, a technique of d.c. injection has been employed to provide heavy electro-dynamic braking. The motor contactors are arranged so that, when the a.c. excitation is removed from the stator, d.c. excitation is applied in its place, thus setting up a stationary magnetic field which induces the dynamic braking.

As applied to the mill, this technique of on/off control is at present in its most elementary form. Stable operation of the system has been obtained with a gauge error tolerance zone as low as ±0·0005in. To reduce this further and still maintain stability, it will be necessary to shorten the contactor operating times. When this has been done, still further improvement may be possible by applying a technique of velocity feedback stabilisation which has been used in on/off control servo-mechanisms of this nature. In this instance a signal would be obtained proportional to the rate of screwing, and injected as a bias into the gauge error indicator circuit. Thus, assuming that the motors are screwing down to restore a required gauge after a disturbance, the rate signal would cause the gaugemeter to show a gauge within the tolerance in anticipation of that actual gauge being achieved. This will cause the screw motors to be de-energised a short time before achievement of the required gauge, in order to allow for the overshoot due to motor inertia. It must be pointed out that a correcting signal proportional to the rate of screwing is not the theoretical ideal required for complete elimination of overshoot in this instance, but it is suggested as a correction which can be readily applied and is better than nothing. If it is assumed that the braking of the motor on de-energisation is entirely electro-dynamic, thus producing a braking force approximately proportional to speed, the final resting position of the motor will be approached exponentially and the overshoot will be proportional to the initial velocity. If, on the other hand, the braking of the motor was entirely due to a fixed frictional force, the overshoot, after de-energisation, would be proportional to the velocity squared. Thus a compromise between velocity and velocity squared is required for the correcting signal. Furthermore, the correcting signal should be derived from rate of change of gauge and not from the screwing rate. The relationship between these two is variable and dependent on the rolling conditions, and since gauge error initiates the control action, rate of change of gauge should be used for correction. If, however, a rate-of-change-of-gauge signal were to be injected into the gaugemeter circuit in the required direction, it would have the effect of unstabilising the gauge-error-indicating servo-mechanism. For this reason it is suggested that a screwing rate signal be accepted, and this signal is already available from the tacho-generator in the servo-mechanism positioning the screw-setting potentiometer. It is thus necessary to inject only a part of this signal into the d.c. stage of the gaugemeter servo amplifier to introduce the required velocity feedback stabilisation.

Automatic Gauge Control by Continuous Action.—By the use of the equipment available, a system of automatic gauge control can be operated in which a correction to the screws, or other devices affecting the gauge, can be applied which is proportional to the gauge error. To do this the servo amplifier, at present actuating the gauge error indicator, would be switched to the appropriate control field of a metadyne or Ward

Leonard set for screw position control or to an electro-hydraulic valve in a hydraulic control system. Relays have already been wired up in the electronic rack to effect this change over. With this system, however, there would be no indication of gauge error when operating under automatic gauge control. In order to provide a simultaneous gauge error indication it will be necessary to add an extra amplifier channel consisting of a pre-amplifier and servo amplifier. These amplifiers would be used to generate the error signal to actuate the automatic gauge control leaving the gauge error indication unaffected. The inputs to the additional pre-amplifier would be from the roll force bridge output and gauge setting control circuit only, thus excluding the signal from the resetter potentiometer.

Automatic Tension Control

Facilities have been provided for automatic tension control based on measured tension instead of by the present system of control of coiler motor armature current with correction for radius which gives only an approximate automatic tension control system.

The method provided uses the tension indicator unit with its potentiometer to set the required tension, and the output of the servo amplifier normally associated with the tension indicator is switched over to the control winding of the machine determining the coiler tension. Thus, any deviation of tension from the value set on the indicator gives rise to an error signal actuating the servo amplifier and so generates the necessary control action. The switch-over of the servo amplifier output is effected by a relay which is already wired up in the electronic rack. In order to set the pointer of the tension indicator unit at the particular tension set by a knob on the control desk, an M type step transmitter is used. This is a step transmission system using d.c. energised rotary transmitter and receiver elements. An M-transmitter on the control desk is energised when the system is switched to automatic control. Also a magnetic clutch in the indicator unit is made which couples an M-receiver to the pointer shaft, thus permitting its adjustment remotely from the desk.

There is an alternative system of automatic tension control which may be slightly less convenient in operation but does not require a remote transmission system. In this, the tension is indicated normally and brought up to the required value under the existing manual control. The output of the servo amplifier operating the indicator unit can be switched to the control field of the machine determining tension, and thereafter the tension will be held at the set value. The operational inconvenience of this system is that to change the tension setting it is necessary to revert to manual control and then back to automatic control. The system has, however, the advantage that the amount of tension adjustment to be made through the winding of the machine controlling tension is small compared with the first method described, which has to give sufficient control action to operate over the whole range of tension. This system may be more suitable for the existing electrical control system.

Conclusions

The system of measurement and display of roll loads, strip tension and strip gauge described in the paper has shown itself very satisfactory in service and has served as a useful model upon which industrial instrumentation schemes might be based. The rationalisation of the electronic units and the choice of a potentiometric system of display have helped greatly in getting this comprehensive scheme quickly into service.

Experiments so far carried out with a simple system of automatic gauge control by on/off control of the screw motors, using the gauge error indicator to initiate the control action, have shown that this system has considerable promise for use on some industrial mills.

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Continental Engineering News

European Steel Production in the Third Quarter of 1955

Figures published by the United Nations Economic Commission for Europe* show that European steel production during the third quarter of this year has again increased. Production in the period under review attained the following annual rates, in millions of metric tons: German Federal Republic 22, United Kingdom 18·5, France 11·7, Belgium 5·8, Italy 5·3, Saar 3·3, Luxembourg 3·2, and Netherlands 1·0. In certain cases production was considerably affected by the usual incidence of summer holidays, but the existing records for the quarter—which in all cases except in that of Luxembourg occurred in 1954—were surpassed in all the countries by the following percentages: German Federal Republic 18, United Kingdom 8, France 11, Belgium 15, Italy 30, Saar 8, Luxembourg 2, and Netherlands 5.

Statistics relating to imports and exports of finished steel are brought up to the end of July. In general, imports during the second quarter continued at the high levels reached earlier in the year and, except in the case of Italy, were at a higher rate than in any previous post-war year. A similar state of affairs prevails with regard to exports, the exception here being the United Kingdom where, owing to the effects of the railway and dock strikes in June and July, the average for the quarter did not reach the 1950 peak.

This increase in Western European trade in finished steel is mainly due to intensified exchanges between the countries of the European Coal and Steel Community. The report also gives figures for the trade in iron ore, coke and scrap, which was in general at a high rate corresponding to that of steel production. Details are also given of steel deliveries to some twelve consuming industries, covering about 80 per cent of the total steel consumption of Western Europe.

European Rolling Stock

The third conference of European transport ministers which ended in Berne recently has led to an agreement to form a company for the international financing of purchases of railway equipment. The company is to be called "Eurofima" and will have its seat at Basle. Capital is to be 50,000,000 Swiss francs. The agreement was signed on behalf of Austria, Belgium, Denmark, France, Western Germany, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Yugoslavia. Britain, Greece and Turkey, the only other members of the seventeen-nation conference did not sign the agreement. After parliamentary ratification it will come into operation for fifty years.

The purpose of Eurofima is to procure on the best possible terms railway material of a unified type or unified performance. It will place construction orders, either on its own account or on the account of railway administrations or other organisations. When orders are placed, the material will be hired out or sold to interested parties. The company will seek finance independently of its own capital, in the form of loans.

European rolling stock is in urgent need of renewal, since out of a total of 940,000 wagons, some 140,000, or 15 per cent, are more than forty-five years old, and 42 per cent are more than thirty-five years old.

West German Inland Shipping

An increase in traffic of 8 per cent for the first nine months of 1955 is reported for the West German canal system. At Münster the traffic during this period amounted to 11·5 million tons compared with 10·6 million tons during the same period last year. It is at Münster that shipping from the Ruhr district moves northwards in the direction of Emden and eastwards in the direction of Berlin. Shipping facilities at the present time are said to be fully extended, so that small delays, some due to the weather, are often unavoidable. It is stated, however, that earnings are below their possible level, largely owing to the fact that capacity on the Ruhr-Emden run is utilised at less than its full value. The export of coal to Emden is much below the volume of imports from that port, which consist mainly of iron ore. As a result, during the first three quarters of the current year, about 1,000,000 tons capacity had to be run to Emden empty.

* *Quarterly Bulletin of Steel Statistics for Europe*, Vol. VI, No. 3. Geneva: E.C.E. Price 7s. Obtainable from H.M. Stationery Office, Mail Order Department, Cornwall House, Stamford Street, London, S.E.1.

The Swedish Engineering Industry

According to a report by the Swedish Institute of Industrial Research, the stock of orders in the Swedish engineering industry in August amounted to 354 million man-hours, corresponding to nine months' employment. The share of exports in the total production was 31 per cent. These figures were almost identical with those published for February, while in August of last year the order book totalled 360 million man-hours, of which exports constituted 29 per cent.

As regards the separate branches of industry, the figures were as follows, with those for 1954 shown in brackets: shipyards had orders for fifteen months (twenty); electrical engineering, thirteen months (eleven); mechanical engineering, nine (eight); steel and other metal producing industries, four months (four). Highest percentage of export orders is that of shipyards with 63 per cent (52 per cent in August, 1954).

Swedish Cement Manufacture

During the past two decades the consumption of cement in Sweden is stated to have increased at an annual rate of 6 to 8 per cent. While 1,100,000 tons were produced in 1939, the output in 1955 was 2,500,000 tons, including 300,000 tons for export. Since 1939 about Kr.-300 million has been invested in extensions. The concrete industry, which makes pipes, building blocks, roofing tiles and other items, is one of the most quickly expanding industries in Sweden. Progress in cement output is closely linked with that of the building industry, which has increased its output by 60 per cent since the years just before the war. Employment in the building trades has increased by one-third since the end of the 1920s, i.e. by 60,000 to 70,000 hands. Rationalisation and new methods have increased productivity, and building during the winter season is on the increase. Further demands for cement are likely to arise from the growing manufactures of such products as prefabricated sections and concrete railway sleepers.

Technical Digests

In order to make available to wider circles the information published by the technical press in Western Europe and North America, the European Productivity Agency (E.P.A.), 3, rue Pascal, Paris (16e), is organising the issue of monthly abstracts, under the name of *Technical Digests*. In each of the participating countries (Austria, Denmark, France, Great Britain, Italy, The Netherlands, Norway, Sweden, Switzerland, West Germany, and the U.S.A.), a staff of experts abstracts information concerning new developments in industry. In general, the scope of each abstract is not confined to one source, but an attempt is made to draw upon as wide a range of contemporary knowledge as possible in order to give a more complete résumé of the matter in question. After translation into English or French, the abstracts are sent to the Paris headquarters of E.P.A., where they are checked. A selection of about 100 per month is made and forwarded to the national agencies, which circulate lists of titles and the abstracts themselves. They are available in Great Britain from the D.S.I.R. Technical Information and Documents Unit, 15, Regent Street, London, S.W.1. Individual lists and pamphlets are free, but complete monthly sets cost 8s.

Ghulam Mohammed Barrage in Pakistan

BY OUR INDIAN CORRESPONDENT

THE Ghulam Mohammed Barrage at Kotri, which was inaugurated on March 15, 1955 (see THE ENGINEER, March 25, 1955) by Mr. Ghulam Mohammed, the then Governor-General of Pakistan, after whom it is named, is the second control works on the River Indus, the first being the Sukkur Barrage, opened for irrigation in 1932. The Sukkur Barrage is one of the biggest of its kind in the world, commanding a total area of 7·5 million acres, of which over 5·5 million are cultivable. Its canals, with a total length of 6473 miles, have an aggregate discharge of 46,617 cusecs. The barrage turned the province of Sind from a region of deficit into one of surplus, whose annual production of food grains and cash crops has been estimated at over 2,000,000 tons. Before the barrage the cost of supply from irrigation wells came to Rs. 125 per acre, the perennial supply under the barrage system costing only Rs. 35 per acre.

The Ghulam Mohammed barrage is about 200 miles downstream from Sukkur and is somewhat smaller, the gross area commanded being 3·2 million acres. Of this, over 2·75 million acres are cultivable, the new area brought under command being 1·5 million acres. The barrage itself is 3000ft long and is designed to pass a maximum flood of 875,000 cusecs. The maximum discharge of the canals will be of the order of 25,000 cusecs. The entire project involves an expenditure of Rs. 24 crores (about £25,000,000), the barrage itself costing Rs. 5·75 crores. Work on the project was commenced in November, 1946, when excavation of the Kalri Baghar feeder was taken in hand. Work on the barrage proper was begun in October, 1949. The completed barrage is illustrated herewith.

The barrage consists of forty-four bays each of 60ft span, provided with gates 21ft high, which head up the waters 20ft above the crest. It is provided with a lock for river traffic, the portion of the road bridge over the lock being designed for lifting. A lock is also to be provided over the Fuleli Canal (one of the four main canals), which will be navigable over a portion of its length. Two divide walls, one on either side, enclose the "pockets" containing the head regulators of the canals. The regulators have silt excluders, which retain the heavier grades of silt inside the pockets; when enough silt is deposited the pocket gates are lifted and the silt scoured down the river. There are two fish ladders in each of the divide walls, consisting of a series of pools with 1ft difference of level between each successive pool. There is a 20ft wide road bridge on top with footpaths 4ft wide on each side. The road bridge is carried on pre-stressed precast beams, this being the first occasion in which this method of construction has been used in Pakistan. A steel overbridge carried on steel trestles has been provided for the operation of the gates.

There are three main canals leading from the barrage. On the right bank the perennial Kalri Canal with 9100-cusec capacity, will be traversed through a series of depressions, which will be flooded to form a lake about 20 miles long and 45 square miles in area. This lake will afford facilities for the production of hydro-electric power by the use of a 22ft head, giving 10MW capacity, and it will also act as a reserve water supply for Greater Karachi. On the left bank the barrage will feed the existing Fuleli Canal, whose capacity of 11,000 cusecs will be increased by about 2500 cusecs. From Fuleli a new branch (Guni) is being constructed to give non-perennial irrigation to a large block of new land outside the present command. Alongside the Fuleli Canal a new canal, the Pinyari feeder, with a designed maximum capacity of 14,350 cusecs is being constructed. A third canal takes off on the left bank for the perennial irrigation of two blocks of land at present receiving non-perennial supplies from Fuleli. The canal will have a capacity of 4100 cusecs and is being lined with cement concrete to obviate the dangers of water-logging. This is the first time a major canal is being lined in Sind.

The hydro-electric possibilities in this part of the country are extremely limited and the only major installation for some time to come will be the one on the Kalri Canal mentioned above. A few other falls may be utilised should need arise, but the prospects of reasonably cheap power from Sui gas (whose pipeline incidentally is carried across the Indus over this barrage) may not call for an intensive hydro-power development in this region.

Some salient features of the barrage are tabulated below. The barrage as originally designed in 1946 was estimated to cost Rs. 7·01 crores. The revised estimate in 1951 when the project was redesigned called for an expenditure of Rs. 5·1 crores. The cost so far is of the order of Rs. 5·75 crores. The construction was mechanised to a far greater degree than is the normal practice in this part of the world. There were initial difficulties about flood diversion. Floods in March, 1954, had to be passed partly over the barrage and partly in the diversion channel. The barrage was constructed departmentally and most of the staff, with the exception of the chief engineer and a few other engineers, almost all of them from Great Britain, was from Pakistan. With one partial exception all the canal works are being executed either directly or by Pakistani contractors. About two-thirds of the canals have been completed and lining is proceeding apace. The left bank feeders were opened this year, but the right bank feeder (lined) may not be ready until the middle of 1956.

Ghulam Mohammed barrage. Downstream view showing headgear and counterbalances for the sluice gates

The Ghulam Mohammed or Kotri barrage on the River Indus in Pakistan. The upstream side of the barrage is illustrated here

Statistics of Ghulam Mohammed Barrage, on the Indus River.

Gross area commanded	3·2 million acres
Cultivable area commanded	2·75 million acres
Headworks:	
Length of barrage between abutments	2984ft
Number of spans, each 60ft	44
Sill level	48·0ft
Pond level	68·0ft
Downstream bed level	35·0ft
Maximum flood level (upstream)	80·1ft
Maximum recorded discharge	710,000 cusecs
Maximum design flood	875,000 cusecs
Canals:	
Full supply discharge of canal regulators:	
(1) Pinyari (58·6 miles long)	14,350 cusecs
(2) Fuleli (56 miles long)	13,500 cusecs
(3) Kalri Baghar (42 miles long)	9100 cusecs
(4) Lined canal (70 miles long)	4100 cusecs
Width of Pinyari feeder at the surface	285ft
Width of Fuleli feeder at the surface	300ft

Another irrigation project now in the design stage is the Gudu barrage on the Indus, about 90 miles upstream from Sukkur. It will feed the land north of the Sukkur barrage and will command an area of 2,294,910 acres, of which over 2,000,000 will be cultivable. The barrage is estimated to cost about Rs. 2·73 crores and construction is planned to be completed within four years. Orders for the machinery, &c., are in the process of being placed. An interesting aspect of this project is that it will command 311 square miles of Baluchistan in an area adjoining Afghanistan, whose claim over it has led to certain ill-feeling between the two countries.

Industrial and Labour Notes

Full Employment

The British Employers' Confederation has circulated this week a document entitled *B.E.C. Viewpoint*, in the first part of which it comments on the recent statement on economic affairs by the Trades Union Congress. The Confederation says that the T.U.C.'s conclusion that rising costs and prices are the biggest threat to our balance of payments, to continuing full employment and to living standards is common ground with employers.

The Confederation goes on to comment that the T.U.C. appears to recognise that our economic difficulties arise largely from an exaggerated concern "to preserve under the guise of full employment a situation in which we are all bidding each other up for scarce resources, particularly our limited supply of labour." Relief of excess demand, the Confederation says, would not involve reduced production or reduced employment, but it would, however, eliminate frustration and wasted time. Full employment, as practised to-day, the Confederation adds, means too often that because of bottlenecks employers are encouraged to try to recruit and retain in temporary idleness labour for which they have an anticipated but not an immediate need. The Confederation then recalls that, in its recent statement on Britain's industrial future, it pointed to a reduction of Government expenditure as being the most promising direction in which to look. The Government, it observes, has taken steps which should have the effect of reducing expenditure by local authorities and relieving the excessive pressure placed on our overstrained economy. What is essential, the Confederation emphasises, is that the Government should show that it is really determined to take all necessary measures to restore stability to the pound sterling so that all, including employers and workers, are convinced that the Government "really means business in this matter." They will then, it is remarked, abandon habits of mind which have developed during fifteen years of continued inflation and adjust their own expectations and policy accordingly.

Trading Conditions and Government Policy

In his chairman's address at the annual meeting of the Birmingham Small Arms Company, Ltd., which was held on Monday, Sir Bernard Docker said that the struggle to combat ever-increasing competition both at home and abroad occupied a prominent place in the outlook of British industry. The rapid revival in the productive capacity of Germany and Japan, and, indeed, in less degree of other countries, must be faced with all the resources of skill and craftsmanship.

The policy pursued by the Government needed, in the interest of national economy, widespread constructive revision. To adjust the vital relationship between British import and export trade, Sir Bernard added, demanded carefully considered positive action by Government, industrial organisation, and enlightened and balanced trade union co-operation. The main objective of a Chancellor, Sir Bernard continued, should be the reduction of abnormal Government expenditure and its consequent burden, and the stimulation of export business by incentives in the basis of taxation. If, he observed, Chancellors had had the courage to insist that in peacetime nothing beyond the safe limits of exaction from industry and individuals would be available for Goverment departments to spend, a good deal of the impetus to inflation would have been absent.

Profit Sharing

In a statement accompanying the annual report of Barclays Bank D.C.O., the chairman, Mr. J. S. Crossley, makes some comments about the attention which has recently been focused "in high places" on the subject of profit-sharing in industry. The term, he says, has an appealing sound, but is somewhat lacking in definition. There is, for example, the statement continues, a sense in which it is true to say that all employees depend upon the profits of industry, for the ability of any industry to provide a livelihood for its workers depends, in turn, on its ability to pay its way and to prosper. While this is not profit-sharing in the generally accepted sense of the term, Mr. Crossley observes, the fact that the fortunes of the employees are inevitably bound up to a greater or less extent with the fortunes of the industry itself should not be overlooked.

Mr. Crossley then goes on to suggest that the next stage in profit-sharing may be said to come with the paying of a bonus on results. The bonus itself may be geared directly or indirectly to the actual profits earned in any particular year. Where the link is direct, the statement says, true profit-sharing is established, and this, Mr. Crossley asserts, may very well prove more remunerative to the employee than a system of stock ownership where dividend distributions may be governed by more conservative policies. But, Mr. Crossley observes, the practical problems involved in profit sharing are not easily solved. Amongst the most formidable of the problems, he points out, is that of ensuring that not only that there shall be profits, but that they shall be maintained and, if possible, increased, and above all that they shall not fall. It is all too easy, the statement suggests, in an era of inflationary trends, to forget that profits are subject to sharp fluctuations, downward as well as upward, while dividends have an uncomfortable habit of vanishing altogether. It is unfortunate, Mr. Crossley adds, that statements from high places, as well as from less responsible quarters, frequently confuse the issue by seeming to suggest that a close relationship necessarily exists between dividends and wages, quite overlooking the fact that, unlike dividends, wages seldom fall.

Automation and Electronics Bill

The text of the Automation and Electronics Bill—a Private Members' Bill—was published at the end of last week. The purpose of the Bill is "to provide for the establishment of a permanent committee to inquire into, review and report on the social, educational, cultural and economic needs and consequences of the application of automation and electronic devices to British industry and agriculture." For the purposes of the Bill the expression "automation and electronics" is interpreted as: the movement of materials and parts from one operation to the next automatically; the replacement of men in the operation of machines by automatic and electronic devices; the replacement of inspectors by electronic control devices which inspect products automatically; the use of mechanisms which count, fill orders, maintain inventories, re-order and give instructions and automatic preventative maintenance; and the use of farming machines which plough, harrow, seed, fumigate and fertilise in one operation.

Safety in the Ironfoundry

The Council of Ironfoundry Associations has published, as a booklet, a paper entitled "Safety in the Ironfoundry," which was presented by Mr. Colin Gresty at a conference of the Royal Society for the Prevention of Accidents earlier this year. Mr. Gresty is the chairman of the Council's safety committee.

The paper comments on the diversity of castings produced in ironfoundries, pointing out that, although foundries of all kinds have much in common, they also have important differences, due mainly to the materials they use and to the temperatures involved in their respective processes. In round figures, Mr. Gresty explains, there are about 1900 ironfoundries in Great Britain, ranging from those employing ten men or less to those employing over 400. In September, 1953, there were in fact 400 ironfoundries in which up to ten men were employed, and 1270 foundries (68 per cent of the total number) employing up to fifty people each. The paper goes on to mention the variation in safety considerations throughout the ironfoundry industry. It is clear, Mr. Gresty says, that with so many small units in the industry a national campaign on any subject, such as safety and health, is presented with many difficulties. The efforts of the safety committee, set up by the Council of Ironfoundry Associations in 1953, are, however, encouraging all ironfoundries to take a lively interest in safety matters. The aspects of safety dealt with in some detail in the booklet include dust control, eye protection, foot protection, and guards for plant and machinery. Copies of the booklet are available, free of charge, from the Council of Ironfoundry Associations, 14, Pall Mall, London, S.W.1.

Industrial Welfare Society

The Industrial Welfare Society has issued the annual report of its council, which deals with the activities of the Society in the year ended June 30th last. The report says that the Society endeavours to remain practical and to take account of all the economic factors with which industry is concerned. Understanding of people, their motivations, attitudes, reactions and ambitions is the first step, it is added, towards securing their interest in a joint activity. From this, the report says, there can spring a recognition of a common purpose and the acceptance of joint responsibility, on which basis efficiency can best be achieved.

The council's report includes a report by the Society's director, Mr. John Marsh, who says that a good deal of attention is given to-day to the high standards of scientific and technical achievement. Side by side with this, however, there is a great need for men who have personal qualities and who can influence workers at all levels to be self-respecting, co-operative and efficient. Personal qualities, it is urged, are not only needed among those concerned with management, but also among the specialists. Mr. Marsh goes on to suggest that the technical specialists of industry can create human problems which sometimes offset the efficiency they set out to achieve. For example, the need for work study engineers is undoubtedly great, but industry must select men for training in these tasks who are fundamentally sound in their knowledge and understanding of their fellow men. They must certainly know something about the effect of changes in skill on a man's reasons and emotions.

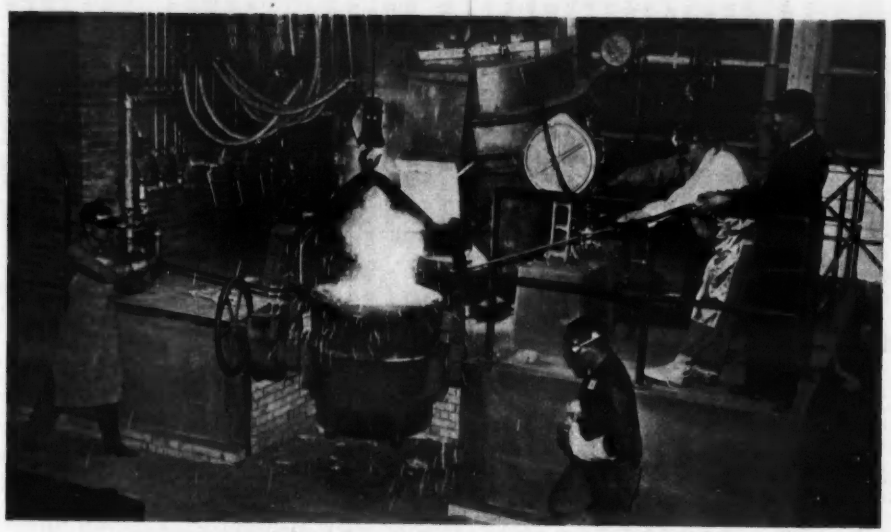
Another matter on which the director comments is the problem of promotion. There are few companies, he says, which have a clearly defined promotion system. The problems of management and supervisory succession, much to the fore in all industries, would be less acute, it is asserted, if every manager were encouraged to seek out and train one or two successors for his job. In fact, Mr. Marsh observes in his report, it could well be argued that a manager who leaves a vacuum in his department on retirement or change of job, has failed to complete his work. The natural encouragement of successors would more often ensure the continuance of wise and just labour policies, for consistency is essential to integrity.

Employment of the Elderly

The National Advisory Committee on the Employment of Older Men and Women has presented its second report to the Minister of Labour. The report says that encouraging progress has been achieved in promoting the employment of older people, but adds that there is room for "further experiments and research to overcome the difficulties which remain." The committee urges that there is a continuing need for firms to examine the age structure of their establishments, and that it is desirable for industries to promote research into aspects of the employment of older workers which are their particular concern. The report is published by H.M. Stationery Office.

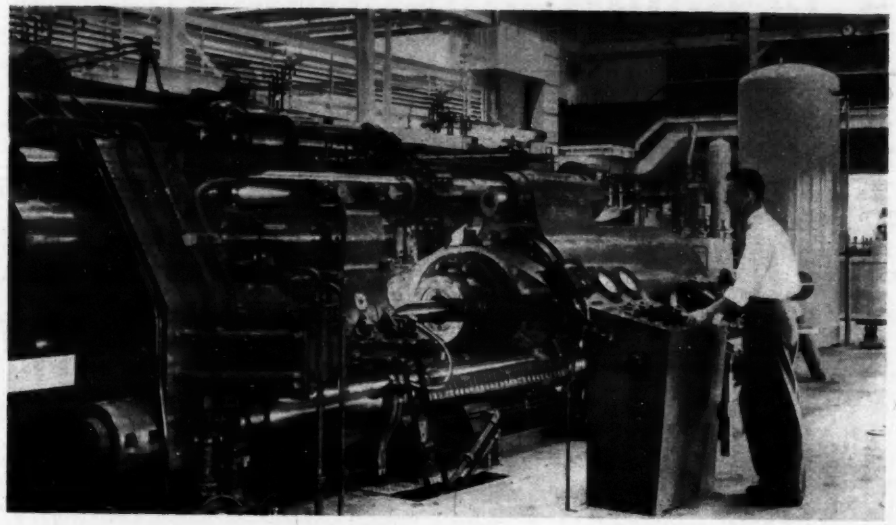
METALS AND CERAMICS RESEARCH LABORATORY AT SCHENECTADY

General Electric research laboratory. The new metals and ceramics building is near the water tower



One-ton-capacity three-phase arc melting furnace being tapped into ladle

Mechanical working bay, including drop forging hammer, extrusion press and hot and cold rolling mills



1250-ton "Hydropress" hydraulic extrusion press having a very fast extrusion rate to limit heat loss

Metals and Ceramics Research Laboratory at Schenectady

BY OUR AMERICAN EDITOR

The Metals and Ceramics Research Laboratory of the General Electric Company at the Knolls, near Schenectady, New York, was officially opened recently. The new facility is equipped with advanced processing and testing plant allowing the production of various engineering materials on a considerable scale. Pilot plant installations in such fields as melting, forging, rolling and extrusion will enable the company to conduct research and development work without requiring the assistance of the usual suppliers of metals, alloys and other engineering materials.

THE recent opening of the Metals and Ceramics Building at the Research Laboratory of the General Electric Company illustrates an interesting trend currently to be found in the American engineering industry : to have available one's own metallurgical processing facility in order to be independent of producers of ferrous and non-ferrous metals. The General Electric installation has been conceived on a considerable scale ; it involved an expenditure of 5,000,000 dollars and now has a staff of 100. Among the many problems with which the new experimental facility is concerned is an investigation of magnetic sheet steel. The goal is not to manufacture but to promote shorter delivery time in getting new materials into production. The facility will permit the firm to obtain new special alloys in a week instead of waiting perhaps several months to have them made by a steel or non-ferrous mill. The pilot work will now be greatly accelerated and the scientists will be in closer touch with all steps of the process or experiment. The main objectives of the new laboratory building at the Knolls are : (1) to ascertain and analyse the areas of most critical need for materials and processes ; (2) to develop new processes for new businesses ; (3) to develop new materials to improve products; (4) to study existing materials and obtain a better understanding of their properties and processing ; (5) to operate pilot plants and obtain economic data.

The new metals research building possesses remarkable structural, operational and experimental flexibility. Extensive changes in equipment can be made readily for new projects and investigations. New processing systems can be easily installed and old ones quickly rearranged. This is facilitated largely because piped services and electrical power are available at almost any location. The research laboratory scientists themselves did much of the planning of the building and the design of the equipment. Equipment will come and go and there will be constant changes as new processes present new and unpredictable requirements. Portions of equipment used in a pilot plant operation may find their way into a new production plant at some other site.

Examples of current projects now being carried on in the new building concern new materials for turbine buckets in jet aircraft engines, new alloys for magnetic applications, the developments of economic production techniques for metals such as titanium and zirconium, and a study of economic melting and fabricating processes for nuclear metals. Each of the operations of the processes laboratory is headed by a member of the technical staff, who is assisted by skilled mill operators and by laboratory assistants who follow and guide the work. This organisational arrangement places the responsibility for the work squarely on the shoulders of the scientists, and thus ensures that the most comprehensive technical understanding is applied to every project. Both office space and individual laboratory rooms are provided at the new building in addition to the extensive processing facilities. Laboratories situated on the ground floor include a chemical analysis area, a metallographic facility, a general-purpose room for small-scale experimental work, testing facilities for magnetic and dielectric materials, and other testing equipment.

Building Layout

At first glance, the new building, which measures 312ft by 160ft and has more than 75,000 square feet of floor space, seems more like a factory than a laboratory. Since ideas for new materials and processes frequently come from the " test tube " development work done in the basic research areas of the laboratory, many of the properties desired in such materials can be tested only by trying them on a scale approaching actual industrial conditions. Thus, a building capable of doing this work necessarily must be nearly factory size. However, there is an obvious difference between this facility and a factory. Here the standard equipment as well as the special equipment is operated under laboratory conditions, with emphasis on measurement and control, and freedom from production schedules. These pilot operations also must be of a transitory nature, as ideas do not come to the new building to stay—they are either forwarded to production departments for actual use or sent back to the basic research scientists for further investigation. Then the building must be readily adaptable to the next project. The new metals and ceramics building, therefore, has an internal structure like an " erector set," permitting quick assembly and easy alteration as a process is developed and perfected. Thousands of bolting holes, aligned throughout the building, from floor to roof, provide the required versatility. Travelling cranes can lift new structural members into place, and move heavy apparatus into more convenient locations. Power supplies and service facilities have been distributed on a " modular " arrangement to permit flexibility. Services available " on tap " basis include compressed air, high and low pressure steam, town's gas, nitrogen, oxygen, standard hydrogen, dried hydrogen (—90 deg. Cent. dew point), rough vacuum, distilled water, cooling water and hot and cold tap water.

Processing Facilities

To maintain the maximum opportunity for scientific interchange the ceramics facilities in the new building are closely integrated with those of metallurgy. An extensive area for ceramics formulation, heat-treatment and testing adjoins a similar metal treating area. An unoccupied area has been set aside in anticipation that still more facilities will be needed as metallurgists and ceramists pool their knowledge to obtain metal-ceramic composites having outstanding properties. For the metallurgists the facilities of the new building are divided into three general areas : melting, hot working and cold working.

The equipment installed for the melting and casting of alloys is of a design that became available only in recent years. During melting the metal must be protected from the contaminating effects of atmosphere, and therefore it has been necessary to design arc melting furnaces capable of melting the most refractory metals under vacuum and in inert gas atmospheres. In one of the new furnaces ingots of " super-alloys " weighing up to 600 lb can be turned out. Advanced designs now being formulated may enable the furnace to produce a continuous ingot of " super-alloy " weighing about 4000 lb. A smaller 50 lb vacuum arc melting furnace is available to keep the research staff supplied with alloys at an earlier stage of evaluation, and a number of similar laboratory size furnaces will fill the needs of the scientists requiring small quantities of many kinds of alloys for their investigations. Air and vacuum induction melting is available with furnaces ranging in capacity from 5 lb to 500 lb. An industrial three-phase a.c. arc furnace has been installed for the preparation of 1-ton heats of steel, under conditions equal to the best attainable in industry. This facility is intended to accelerate the difficult process of final analysis of many new alloys, both on the basis of properties and of economic feasibility.

Many of the " super-alloys " to be handled by the new laboratory will be given an initial deformation after casting by extrusion. The 1250-ton hydraulic extrusion press in which this operation is performed has been specially designed for fast extrusion of " super-alloys." Once the cast ingots have been given the initial deformation they can be further worked by conventional rolling and forging techniques, except that the metals to be worked are far stronger than the metals commonly in use, including those used in building the conventional metal working machines. It has been said that if conventional equipment had been installed in the new building the experimental alloys would " deform the machines rather than the machines deforming the alloys." The research laboratory personnel collaborated closely with machine designers to obtain equipment capable of performing the desired " conventional " operations with uncommonly strong " unconventional " material. The 10in and 16in rod mills are examples of the specially designed equipment. They deform high-strength alloys, such as jet engine bucket materials, by performing their operations very rapidly. Pieces of metal initially at a very high temperature are thus reduced to final size before they cool to a temperature where the extreme strength properties are realised.

The seven laboratory areas situated on the main operating floor are : (1) foundry laboratory, (2) vacuum and inert arc melting laboratory, (3) vacuum induction melting laboratory, (4) fabrication laboratory (hot and cold), (5) heat-treatment laboratory, (6) powders laboratory (metals and ceramics), (7) coatings laboratory. The hot fabrication laboratory equipment includes: (1) a 1250-ton extrusion press, by Hydropress, Incorporated, of New York ; (2) a hot slabbing and rod mill, by the Birdsboro Steel Foundry and Machine Company, of Birdsboro, Pennsylvania ; (3) a Sendzimir planetary hot strip mill, by the Precision Methods and Machines Company, of Waterbury, Connecticut ; (4) a reversing hot mill, by the Fenn Manufacturing Company, of Hartford, Connecticut ; (5) two Chambersburg hammers and a small Nazel hammer. The cold working equipment includes : (1) a reversing cold strip mill, (2) a Sendzimir cold strip mill, (3) three small cold rolling mills, (4) six swaging machines, (5) several wire-drawing machines and a 100-ton press.

Van de Graaff Generator for Studying Irradiation of Materials

A THREE-MILLION-ELECTRON-VOLT Van de Graaff particle accelerator is being built by the High Voltage Engineering Corporation, Cambridge, Mass., and will be installed in June, 1956, in the Emeryville, Calif. research laboratory of the Shell Development Company, U.S.A. There it will be used for studying the effects of radiation on fuels, lubricants, plastics and other products derived from oil.

In this version of the Van de Graaff generator charged particles produced by " spraying " on a moving belt are emitted from a heated cathode at one end of a high-voltage vacuum tube and are accelerated, in the form of a high-intensity beam of electrons, along this tube. At the other end of the tube the particles are made to impinge on the material that is being irradiated. The moving belt, the electrode system and the vacuum tube are enclosed in a cylindrical shell.

Physical changes are produced in matter subjected to this form of bombardment : for example, plastics become harder, their resistance to solvents is increased and they retain their mechanical properties at higher temperatures.

Personal and Business

Appointments

MR. R. H. WEST has been appointed chief buyer of Creators, Ltd., Woking, Surrey.

MR. R. V. BRADSHAW has been appointed a director of M. and B. Plastics, Ltd., Dagenham.

MR. GERALD M. PALMER has been appointed an assistant chief engineer of Vauxhall Motors, Ltd., Luton, Beds.

MR. J. P. FORD has been appointed managing director of Charles Colston, Ltd., 3, Mill Street, London, W.1.

THE EFFINGHAM STEEL WORKS, Ltd., Sheffield, states that its general manager, Mr. J. H. Allan, has been appointed a local director.

MR. H. DALE LANGLEY has been appointed technical manager in the United Kingdom of Square D, Ltd., 100, Aldersgate Street, London, E.C.1.

HENRY BERRY AND CO., Ltd., Leeds, states that Mr. Arthur Walker has been appointed managing director. Mr. D. Coley has joined the board and has been appointed chief engineer of the company.

THE MINISTRY OF SUPPLY announces the appointment of Mr. J. E. P. Dunning as chief superintendent, rocket propulsion department of the Royal Aircraft Establishment, in succession to Dr. T. P. Hughes.

G. A. HARVEY AND CO. (LONDON), Ltd., Greenwich Metal Works, London, S.E.7, states that Mr. G. R. Blakely has been appointed works director. Mr. Blakely has been general works manager since 1952.

DUNLOP LTD. states that Dr. W. C. Davey, manager of the chemical research division at the Dunlop Research Centre, Birmingham, has been appointed, in addition, manager of the compounding research division.

BIRLEC LTD., Erdington, Birmingham, states that Mr. P. F. Hancock, research manager, Mr. A. E. Pickles, manager of the induction heating division, and Mr. J. F. Ross, works manager, have been appointed directors.

MARTONAIR LTD., Parkshot, Richmond, Surrey, announces the appointment of Mr. F. H. Gardner as technical representative for the West of England. Mr. C. P. White has been appointed technical representative in N.E. England and Mr. R. J. Taylor, technical representative in South London.

THE NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD states that Mr. L. H. Dickerson, M.I.C.E., has been appointed chief civil engineer, and Mr. P. L. Aitken, A.M.I.C.E., chief hydraulic engineer. Mr. A. A. Fulton, who was formerly chief hydraulic and civil engineer, has now become general manager of the Board.

THE MINISTRY OF TRANSPORT AND CIVIL AVIATION states that Mr. J. C. M. Sutcliffe, senior engineer and ship surveyor in the South-West of England district office of the Marine Survey Service, has been appointed principal officer of the Northern Ireland district, Belfast. He succeeds Mr. J. W. Thompson, who is retiring.

THE STEEL COMPANY OF WALES, Ltd., announces the appointment of two assistant general managers in the steel division. Mr. R. W. Evans, formerly melting shops' superintendent, is to be assistant general manager (operations), and Mr. I. S. Scott-Maxwell, M.I.Mech.E., who has been chief engineer, is now assistant general manager (engineering and development).

THE MARCONI INTERNATIONAL MARINE COMMUNICATION COMPANY, Ltd., states that Mr. J. H. C. Dalziel has been appointed manager of its Karachi depot, in succession to Mr. T. Moriarty, who has now completed his tour of duty in Pakistan. Mr. Moriarty, who has been in charge of the Karachi depot since it was established in 1949, is returning to this country for leave prior to reappointment.

LLOYD'S REGISTER OF SHIPPING states that Mr. W. D. Lydersen has been appointed principal surveyor to Lloyd's Register for Denmark and secretary to the Danish committee. He is to succeed Mr. L. F. Clausen, who is retiring at the end of the year, after thirty-six years' service with the Register in Denmark. Mr. Lydersen has been with Lloyd's Register for twenty-six years and is a senior ship surveyor at Copenhagen.

THE BRUSH GROUP, Ltd., states that Mr. J. Jones, at present managing director of the National Gas and Oil Engine Company, Ltd., is to become deputy chairman of that company on January 1st. He will relinquish the position of managing director and will be available to all the companies in the group as a consultant. Mr. S. Webster, at present deputy managing director of the National Gas and Oil Engine Company, Ltd., has been appointed managing director.

ENGLISH STEEL CORPORATION, Ltd., Sheffield, has announced the following changes in its constituent companies: Mr. W. D. Pugh has been appointed deputy chairman of the Darlington Forge, Ltd., and is succeeded as managing director by Mr. W. S. Scott; Dr. C. J. Dadswell has been appointed a director. Mr. W. E. A. Redfearn has been appointed assistant managing director of English Steel Forge and Engineering Corporation, Ltd.

MR. W. B. NODDINGS, M.I.E.E., has been appointed head of the commercial department of the Central Electricity Authority. He succeeds Mr. E. R. Wilkinson, M.I.Mech.E., M.I.E.E., who is relinquishing the position at the end of the year to join the boards of Power Securities Corporation, Ltd., and Balfour Beatty and Co., Ltd. The Central Electricity Authority has also announced the appointment of Mr. R. L. Kay, A.M.I.Mech.E., as steam testing engineer of the North Eastern Division, in succession to Mr. P. G. Lloyd, who has retired.

Business Announcements

PRICE MACHINE GUARDS, Ltd., has moved its business to The Gawne, Powke Lane, Old Hill, Staffs.

MAXIM SILENCERS, Ltd., states that its address is now 352, Euston Road, London, N.W.1 (telephone, Euston 7991).

ELECTRICAL ENGINEERS (ASEE) EXHIBITION, Ltd., has moved to 6, Museum House, 25, Museum Street, London, W.C.1.

DR. C. E. KENNETH MEES has retired from his position as vice-president in charge of research of the Eastman Kodak Company.

BROOK MOTORS, Ltd., Huddersfield, has purchased a 28-acre site at Hope Bank, Honley, near Huddersfield, for new factory development.

VACUUM OIL COMPANY, Ltd., Caxton House, Westminster, London, S.W.1, states that it will in future be known as Mobil Oil Company, Ltd.

THE HAWKER SIDDELEY GROUP states that the title of the Brockworth Engineering Company has been changed to Armstrong Siddeley (Brockworth), Ltd.

HEAD WRIGHTSON PROCESSES, Ltd., states that it now undertakes the inspection, maintenance and repair of all water cooling towers, regardless of the make or design.

DILWORTH AND CARR, Ltd., Bow Lane, Preston, announces the retirement of Mr. F. W. Smith from the position of chairman and managing director. He has completed fifty years in the company's service.

ROCKWELL MACHINE TOOL COMPANY, Ltd., Welsh Harp, Edgware Road, London, N.W.2, has been appointed sole agent for the "Eleroda D.1" spark erosion machine manufactured by Ateliers des Charmilles S.A., Geneva.

THE BRITISH THOMSON-HOUSTON COMPANY, Ltd., Rugby, has announced the formation of a new company entitled the British Thomson-Houston Company Central Africa (Private), Ltd. Mr. K. C. Ford is the general manager.

DAVID BROWN TRACTORS (ENGINEERING), Ltd., Meltham, Huddersfield, announces the formation of a separate industrial tractor division. The headquarters of this division are at Hanworth Park, Feltham, Middlesex (telephone, Feltham 5271; telegrams, Industrac, Feltham), and Mr. R. W. Ladbrooke is the manager. The company is also establishing a tractor service and spares depot at Moll Springs Mills, Netherton, near Huddersfield (telephone, Honley 460), where Mr. S. Hallam is to become the superintendent.

Contracts

THE ENGLISH ELECTRIC EXPORT AND TRADING COMPANY, Ltd., has received from the United States Army Corps of Engineers an order for the manufacture and delivery of one 90·75/121MVA, 13·2/161kV, three-phase, 60 c/s power transformer, with accessories and spare parts. It will be recalled that earlier this year English Electric Export and Trading Company, Ltd., was the lowest bidder against the first invitation for this same contract, but all bids were cancelled and the invitation re-issued. The transformer will be installed in the switchyard at Table Rock Dam, on the White River in Taney County, South West Missouri, and will serve two generators, each rated at 52·632 MVA, for which two English Electric 68,000 h.p. vertical Francis water turbines are being supplied. The present transformer for Table Rock Dam will be a three-phase, two-winding, oil-immersed, self-cooled, forced-air cooled, Class OA/FA equipment, which will be dual rated, inert gas-filled, and suitable for outdoor operation.

Miscellanea

SWARF BIN AND TROLLEY.—A portable bin and trolley for removing swarf from machine shops has been introduced by Wickley Ltd., of Chichester. With this equipment a special sheet metal bin is placed beside each machine for the reception of swarf. A trolley which is used to remove the bins raises them by pins set just above the midpoint on each side. At the swarf disposal station a sack is placed over the mouth of a bin, which can then be easily swung over by hand to deposit its contents in the sack.

450 B.H.P. DIESEL MECHANICAL LOCOMOTIVES.—In the article entitled "450 B.H.P. Diesel Mechanical Locomotives," which appeared in our issue of November 18th last, it should have been mentioned that these locomotives, built by Hudswell Clarke and Co., Ltd., Leeds, were in fact designed and built to operate at 500 b.h.p. under normal ambient temperature conditions, up to 85 deg. Fah., and to altitudes of 500ft above sea level. They were derated to 453 b.h.p., as described in the article, for the site conditions in South Africa.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—On Tuesday, November 29th, Mr. C. E. Philips read a paper entitled "Researches on Fatigue of Metals at Mechanical Engineering Research Laboratory, East Kilbride," before the Institution of Engineers and Shipbuilders in Scotland. The paper gives a résumé of current work on pin joints, screw threads, the effect of size of specimen and the propagation of fatigue cracks. Attention is drawn to gaps in existing knowledge and to where further research is required.

MICROMETER SPACING COLLAR.—A new ground thread micrometer spacing collar specially designed for use on slitting and rolling machines producing metal strip has been introduced by Euco Tools, Ltd., 44, London Road, Kingston, Surrey. This spacer consists of an inner collar keyed to suit the machine arbor and having the outside diameter provided with ground threads of micrometer pitch. This collar screws into an outer collar with internal ground threads. The bevelled outside of the outer collar is calibrated into fifty divisions of 0·0005in and a complete turn of the collar equals a spacing adjustment of 0·025in.

ELECTRICITY IN TROPICAL COUNTRIES.—Problems of electrification in tropical countries will be the subject of a two-day study conference in Paris on May 28 and 29, 1956. The conference is organised by an international "Unipede" committee and will deal with plant operation, distribution systems and transmission lines. The influence of climatic conditions on the design and construction of equipment will be examined, with special attention to insulating materials, protection of metal parts and packaging. Further details can be obtained from Mr. V. A. H. Clements (the British representative on the conference committee), Central Electricity Authority, Bankside House, Sumner Street, London, S.E.1.

PROBLEMS OF AIRCRAFT PRODUCTION.—The fourth annual conference of the Southern Section of the Institution of Production Engineers at the University of Southampton will have the theme "Speeding Aircraft Production," and emphasis will be placed on methods which will enable reductions to be made in the time taken to produce aircraft. The proceedings will open with a luncheon on Friday, January 6th, and papers and discussions will continue through the afternoon and early evening and the morning of Saturday, January 7, 1956. The conference fees are 35s. for members of the Institution and affiliated representatives, and 45s. for non-members. Forms of application, obtainable from the secretary of the Institution, 10, Chesterfield Street, London, W.1, will be dealt with in strict order of receipt. Visitors are advised to make hotel arrangements early.

ANNUAL DINNER OF THE SIX HUNDRED "25" CLUB.—The fourth annual dinner of the "25" Club of the George Cohen, Sons and Co., Ltd., "Six Hundred" Group was held in London on November 26th last. Membership of this club is restricted to employees who have served at least twenty-five years with any of the companies within the group, and of nearly 400 who attended the annual dinner, many had worked for far longer periods with their firms. The speeches following the dinner were quite brief, and in one Mr. Felix L. Levy pointed out the responsibility of the older members of the firms in training new entrants. He said that there was need for patience when the younger generation made mistakes, for providing a lesson was learnt by a mistake it was sometimes not such a bad thing as an older experienced employee was apt to think. The evening concluded with a cabaret and concert.

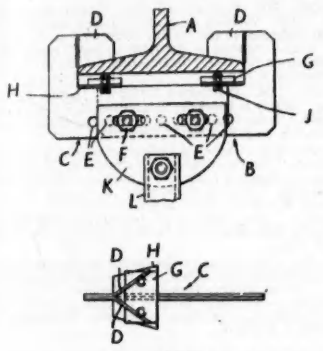
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgement is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgement, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

CONVEYING PLANT

737,389. July 1, 1952.—CLIP ATTACHMENTS, Donald Mayer King, Argyle Works, Stevenage, Hertfordshire, formerly of Hartford Works, Hitchin, Hertfordshire.

The invention has for its chief object to provide an improved attachment for application to rolled steel joists, flanged beams or the like for the purpose of supporting overhead conveyor tracks. The construction of the clip attachment is shown in the drawing attached to the lower flanges of a joist *A*. The two hooked parts *B* and *C* are applied one to each side of the joist so that the splayed ends *D*, shown in the lower view, will engage over the top of the flange, while the longer limbs extend across the bottom of the joist. The two parts are then adjusted to bring the apertures *E* in the longer limbs of each part into register, when bolts *F* are inserted to interconnect the two parts and thus produce a clip which completely embraces the lower flanges of the joist. When in position the plate *G*, which is supported by the tongues or flaps *H* of each part will lie below, and parallel to the underface of the joist, so that on tightening the setscrews *J* these may be used to bite into the underside of the joist to hold the clip securely in position. As the ends of the clip parts *D* are splayed out the clip is completely stable and there is no tendency for it to tilt or move angularly relatively to the joist. To allow for the attachment of hangers or supports for conveyor tracks, a supporting plate or bracket *K* is attached to the clip and is provided with slots or apertures so that the connecting bolts for the fitting *L* may be attached to the bottom of the supporting plate as shown in the drawing.—*September* 28, 1955.

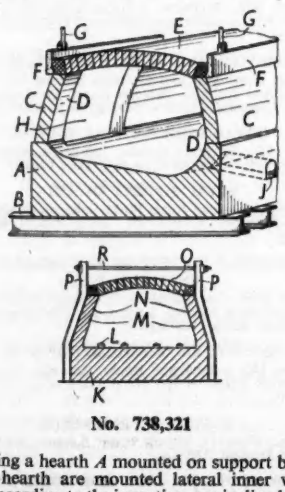


No. 737,389

FURNACES

738,321. March 9, 1953.—FURNACE WALLS, Société Anonyme John Cockerill, Seraing, Belgium.

The invention relates to metallurgical furnaces for melting, refining or reheating and its object is to provide an improved furnace which will substantially overcome roof and wall weaknesses and wear. In the upper view a Siemens-Martin furnace is shown comprising a hearth *A* mounted on support beams *B*. On the hearth are mounted lateral inner walls *C*, which, according to the invention, are inclined towards the interior of the furnace, that is to say, that the internal surfaces *D* converge as they approach an arch *E*. The arch, which is independent of the inner walls *C*, is composed of a number of elements, such as bricks, and is held together in a frame. On both sides of the arch *E*, which overhangs the inner walls, there are placed suspension beams *F*, to which are attached rods such as *G*. In one wall *C* charging doors *H* are arranged with tap holes *J* situated in the opposite wall. In the lower view a reheating furnace constructed according to the invention is shown. In this design a hearth *K*, provided with sliding rails *L* is laterally flanked by inner walls *M*, whose internal surfaces *N* are flat and inclined in a continuous manner between the hearth and an arch *O*. The arch is again composed of a series of elements or bricks mounted in a frame and, if desired, braced. In this design uprights *P* and cross bars *R* for strengthening the furnace are shown. The invention is applicable to all large furnaces in which the heat is supplied by combustion of solid, liquid or gaseous fuel. In furnaces constructed according to the invention the area of the projection of the surface of the independent arch on to a horizontal plane is less than that of the hearth projected on to the same plane. An advantage lies in the appreciable reduction of the span of the arch which results in a decrease in weight of the refractory, increased strength and easier and more rapid repairs. Also in the case where the refractories of the arch and the lateral walls are of different chemical natures capable of giving rise to destructive reactions for one or other of these parts, the structure of a furnace prevents direct contact between the fusion products of the refractory components and, as a result, prevents chemical reaction.—*October* 12, 1955.

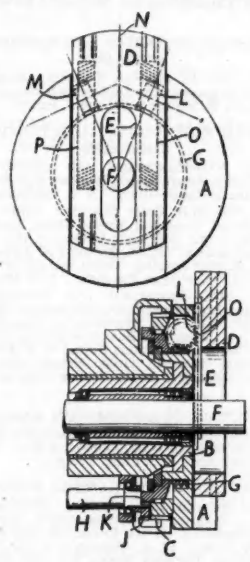


No. 738,321

MACHINE TOOLS

738,873. May 8, 1953.—FACE-PLATES OF HORIZONTAL BORING AND FACING MACHINES, H. W. Kearns and Co., Ltd., of Atlantic Street, Broadheath, near Manchester. (*Inventor: Sir Henry Ward Lionel Kearns, C.B.E.*)

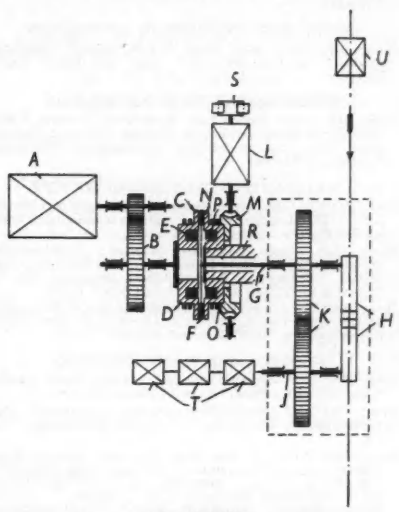
The object of the invention relates to face-plates of horizontal boring and facing machines and it provides an improved worm and worm wheel mechanism for displacing the tool-holding facing slide of the face-plate. Referring to the drawing, *A* is a face-plate mounted coaxially on the main spindle *B* of a horizontal boring machine and rotated by a pinion meshing with spur teeth *C*. *D* is the facing slide, which is slotted at *E* to permit the protrusion of the boring bar *F*. *G* is a worm, mounted coaxially about the main spindle *B* and arranged to be rotated at variable speeds by a shaft *H* through a pinion *J* meshing with spur wheel teeth *K* on the rear end of the body of the worm. The drive of the worm follows standard practice. The worm *G* has a helical rib formed on and surrounding a cylindrical surface, as distinguished from a spiral rib formed on the face of a disc, as shown in the prior Specification No. 499,945. Meshing with the worm *G* are a pair of worm wheels *L* and *M*, one on each side of the longitudinal axis *N* of the facing slide. These worm wheels may be regarded as helical pinions. The plane of each of the worm wheels is, as usual with worm and worm wheels gearing, radial to the worm. Each worm wheel meshes with a different rack *O*, *P* located one on each side of and parallel with the axis *N* of the facing slide, to which both are secured. As the worm wheels are radial to the worm and are on opposite sides of the axis of the slide, they present their teeth oppositely inclined relatively to the axis. The teeth of the racks with which the worm wheels mesh as skew pinions are therefore oppositely inclined. To produce a balanced thrust on the slide the pitch of the teeth of both racks are alike and, to mesh with the worm wheels, equally pitched racks are arranged asymmetrically.—*October* 19, 1955.



No. 738,873

736,599. September 5, 1952.—ROTATING SHEARS, The Loewy Engineering Company, Ltd., 551–553, Wallisdown Road, Bournemouth. (*Inventor: Erhard Rudolf Henschker.*)

The invention relates to rotary shears for cutting moving metal stock, such as billets, bars, rods or strips. In the drawing a shear according to the invention and its main and pilot drives are shown in a diagrammatical manner. The main motor *A* of the shear is connected through a reduction gear *B* and an electric-magnetic clutch *C*, comprising a casing *D* with an energising coil *E* and an axially movable plate member *F*, to a shear shaft *G*. The shaft carries one of the cutter arms *H*, the other cutter arm being mounted on a shaft *J*, both shafts being driven through a pair of gear wheels *K*. A separate pilot motor *L* is provided which is connected by a worm reduction gear *M* to another clutch *N*, substantially similar to the first-mentioned clutch *C* and comprising a casing *O* with an energising coil *P*. The clutch *N* is combined with the other clutch *C* and the plate member *F* to form a change-over unit which permits the alternative connection of the shear to the main motor *A* or the pilot motor *L*. The clutch *N* is mounted on a hollow shaft *R* which is rotatable on shaft *G*. The pilot motor *L* is fitted with an electro-magnetic brake *S*. A set of rotary limit switches *T* for the control of the shear at predetermined points of the cutting cycle is operated by shaft member *J*. A flag switch *U* is arranged in the path, indicated by chain lines, of the stock to be cut. The specification describes the operation of a rotary shear of the oscillating type to which the invention is applied.—*September* 14, 1955.



No. 736,599

STEAM GENERATORS

737,041. June 16, 1953.—FORCED-FLOW STEAM BOILERS, Siemens-Schuckertwerke Aktiengesellschaft, Siemensstadt, Berlin, and Sieboldstrasse 5, Erlangen, Bayern, Germany.

The invention relates to forced-flow steam boilers for operation at overcritical pressure. On the basis of recent investigations it appears possible to make important improvements in the efficiency of steam power plants if the pressure is increased until in the overcritical range and steam temperatures of 600 deg. Cent. and more are used with preheating of the feed water to above 300 deg. Cent. The invention consists in a forced-flow boiler for operation at overcritical pressure and with high feed water temperature, in which an air heater is arranged at the end of the flue gas stream behind the feed water preheater, so that all the combustion air flows through the heater and in which the combustion chamber is operated with positive pressure. The operation of the combustion chamber with positive pressure not only excludes the possibility of the penetration of unwanted air, but also, at the same time, provides the saving from an economic point of view of reducing the power requirements of the auxiliary equipment since an exhaust fan requires a greater driving power than does a blower for producing positive pressure in the combustion chamber. When it is necessary to cool the combustible mixture leaving the coal dust mill, flue gases which have given up a substantial quantity of their heat in the air heater and water preheater are added to the combustible mixture instead of air.—*September* 21, 1955.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Dec. 14th.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Television Aerial Design," I. A. Davidson, 7.15 p.m.——N.E. SECTION: Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle upon Tyne, "The Metal Cone Loudspeaker," W. I. Heath, 6 p.m.

BRITISH WELDING RESEARCH ASSOCIATION

Tues., Dec. 13th.—Lesser Free Trade Hall, Peter Street, Manchester, "What Can be Done to Reduce the Possibility of Fatigue Failures and Brittle Fracture," A. A. Wells, 9.30–11 a.m.; "Recent Developments in the Welding of Steels," A. R. Muir, 11.30–1 p.m.; Recent Developments in Non-Destructive Testing," H. L. Carson and J. Johnson, 2.30–3.30 p.m. and 4–5 p.m.

CEMENT AND CONCRETE ASSOCIATION

Mon., Dec. 12th.—Youth Centre, The Butts, Appleby, Westmorland, "Some Notable Concrete Buildings," R. C. Blyth, 7.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

To-day, Dec. 9th.—Palace Hotel, Buxton, Annual Conference, entitled "The Years Between." (The Years Before Atomic Energy.)

DIESEL ENGINE USERS ASSOCIATION

Thurs., Dec. 15th.—Caxton Hall, Westminster, London, S.W.1, "Report on Heavy Oil Engine Working Costs and Performance, 1954," and an informal discussion on "Operating Problems," 2.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Dec. 13th.—SESSIONAL MEETING: Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Lighting in Buildings: Training and Practice," Derek Phillips, 6 p.m.

Thurs., Dec. 15th.—MANCHESTER CENTRE: Demonstration Theatre, N.W. Electricity Board, Town Hall Extension, Manchester, "Fading and Related Effects Associated with the Radiation from Light Sources," B. S. Cooper, 6 p.m.

Tues., Dec. 20th.—LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, "Lighting in the Rayon Industry," G. E. Shepherd, 6 p.m.

INCORPORATED PLANT ENGINEERS

Mon., Dec. 12th.—DUNDEE BRANCH: Mathers Hotel, Dundee, "Tar Distillation Plant," R. M. Crighton, 7.30 p.m.

Tues., Dec. 13th.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Corrosion Technology," 7.15 p.m.

Wed., Dec. 14th.—E. MIDLANDS BRANCH: County Hotel, Theatre Square, Nottingham, "Grit and Dust Collection," J. E. O'Breen, 7 p.m.——KENT BRANCH: Bull Hotel, Rochester, "Engineering Economics," T. S. Welch, 7 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, "The Plant Engineer and Management," W. J. Dickie, 7.15 p.m.

Thurs., Dec. 15th.—BLACKBURN BRANCH: Golden Lion Hotel, Blackburn, "Fabrication in a Modern Welding Shop," R. M. Watts, 7.30 p.m.

Tues., Dec. 20th.—S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Steam and Utilisation," Films, 7.15 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Dec. 13th.—COVENTRY SECTION: Room A.5, Technical College, Coventry, "History and Development of Aluminium Silicon Alloys," E. Scheuer, 7.30 p.m.

Wed., Dec. 14th.—LONDON BRANCH: Waldorf Hotel, Aldwych London, W.C.2, "Practical Implications of Research on the Casting of Non-Ferrous Metals," E. C. Mantle, 7.30 p.m.

INSTITUTE OF FUEL

To-day, Dec. 9th.—N.W. SECTION: Engineers' Club, Albert Square, Manchester, Symposium "Coke Manufacturing Problems," G. E. Foxwell; "Coke Utilisation," E. H. Coley, and "The Smoke Problem," Andrew Semple, 2.30 p.m.

Mon., Dec. 12th.—N.E. SECTION: Chemistry Lecture Theatre, King's College, Newcastle upon Tyne, "The Complete Gasification of Coal," F. J. Dent, 6.30 p.m.

Wed., Dec. 14th.—MIDLAND SECTION: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Fuel Forum: A Discussion on Mutual Problems," 6 p.m.——E. MIDLAND SECTION: County Hotel, Nottingham, "Grit and Dust Collection from Industrial Furnaces," J. E. O'Breen, 7 p.m.

Thurs., Dec. 15th.—MERSEYSIDE SUB-SECTION: Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, "Instrumentation of Boilers," R. Clare, 7 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Dec. 13th.—85, Minories, London, E.C.3, "The Carriage of Edible Oil and Similar Bulk Cargoes," John Wormald, 5.30 p.m.

Tues., Dec. 20th.—85, Minories, London, E.C.3, "Nuclear Power for Commercial Vessels," Kenneth Maddocks, 5.30 p.m.

INSTITUTE OF NAVIGATION

Fri., Dec. 16th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Handling a Ship," C. J. Wynne-Edwards, 5 p.m.

INSTITUTE OF PETROLEUM

Wed., Dec. 14th.—26, Portland Place, London, W.1, "Statistics as an Aid to Specification," G. W. Sears, 5.30 p.m.——STANLOW BRANCH: Grosvenor Hotel, Chester, "The Shell Hydrodesulphurisation Process," 7.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

To-day, Dec. 9th.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "The Development and Operation of Disc Brakes," T. J. Phipps, 7 p.m.

Mon., Dec. 12th.—SCOTTISH CENTRE: North British Hotel, Edinburgh, "Mobile Cranes in Relation to Transport," C. S. Shaw, 7.30 p.m.——E. REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Maintenance of Fuel Injection Equipment," T. G. Charlesworth, 7.30 p.m.

Tues., Dec. 13th.—EASTERN CENTRE: Swan Hotel, Bedford, "The Development of the Lightweight Diesel," H. L. Parrish, 7 p.m.

Thurs., Dec. 15th.—LONDON CENTRE: Royal Society of Arts, John Adam Street, London, W.C.2. "Maintaining a Mixed Dispersed Fleet," W. L. Gage, 6.30 p.m.——YORKSHIRE CENTRE: Great Northern Hotel, Wellington Street, Leeds, 1, "The Manufacture, Operation and Maintenance of Passenger and Commercial Vehicle Batteries," V. A. Lord, 7.30 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Dec. 13th.—6, Buckingham Gate, London, S.W.1, "Some Factors in the Design of Tractor-Mounted Loaders," Eric Alley, 5.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Dec. 10th.—MIDLANDS BRANCH: Midlands Institute, Birmingham, "The Performance Characteristics of 6in diameter Stedman Packing under Reduced Pressures," Parts I and II, D. G. Cerigo, P. J. King and F. Morton, 3 p.m.

Wed., Dec. 14th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," J. M. Kay and F. J. Hutchinson, 5.30 p.m.

Sat., Dec. 17th.—N.W. BRANCH: Reynolds Hall, College of Technology, Manchester, "Some Aspects of Heat Transfer in a Climbing Film Evaporator," J. M. Coulson, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 13th.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, PARSONS MEMORIAL LECTURE: "The Development of the Gas Turbine," Sir Harold Roxbee Cox, 5.30 p.m.

Wed., Dec. 14th.—N.W. ASSOCIATION: County Hall, Preston, "Non-Rigid Types of Road Construction," A. J. Lyddon, 5.45 p.m.

Thurs., Dec. 15th.—Great George Street, London, S.W.1, Rankine Memorial Lecture, Sir Richard Southwell, 5.30 p.m.

Tues., Dec. 20th.—WORKS CONSTRUCTION MEETING: Great George Street, London, S.W.1, "The Diversion of the Annalong River into the Silent Valley Reservoir," C. F. Colebrook, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day, Dec. 9th.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "Aids to Teaching the Subject of Windings in Rotating Machinery," opened by F. Stefani, 6p.m.

Mon., Dec. 12th.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "The Television Studio as Seen by the Producer," Alvin Rakoff, 5.30 p.m.

Tues., Dec. 13th.—LONDON GRADUATES' AND STUDENTS' SECTION: Savoy Place, London, W.C.2, "Colour Television," L. A. Harris, 6.30 p.m.

Wed., Dec. 14th.—SUPPLY SECTION: Savoy Place, London, W.C.2, "The Measurement of Steam Temperatures in Power Stations," D. H. Lucas and M. E. Peplow, 5.30 p.m.

Thurs., Dec. 15th.—UTILIZATION SECTION: Savoy Place, London, W.C.2, "Intensification of the X-Ray Image in Industrial Radiology," A. Nemet and W. F. Cox, 5.30 p.m.

Tues., Dec. 20th.—S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "High-Speed Electronic Analogue Computing Techniques, D. M. Mackay, 7 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., Dec. 14th.—St. Bride Institute, Bride Lane, Fleet Street, London, E.C.4, "The Bouellat Radiant Water-Tube Boiler," Miss J. E. Gardiner, 6.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Wed., Dec. 14th.—Royal Society of Arts, John Adam Street, London, W.C.1, "The Motor Industry Research Association: its Purpose, Organisation and Methods," W. G. Stevenson, 6.45 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Dec. 13th.—39, Elmbank Crescent, Glasgow, "Light Structures—Research and its Application to Economic Design," R. M. Kenedi, W. Shearer Smith and F. Fahmy, 7.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

To-day, Dec. 9th.—MANCHESTER AND DISTRICT BRANCH: Engineers' Club, Albert Square, Manchester, "Meteorological Data and Design Temperatures," H. C. Jamieson, 6.30 p.m.

Tues., Dec. 13th.—N.E. COAST BRANCH: Institute of Mining and Mechanical Engineers, Neville Street, Newcastle upon Tyne, "Fan Types and Their Choice by the Heating and Ventilating Engineer," H. W. Brown, 6.30 p.m.——SCOTTISH BRANCH: Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2, "Heating by Electricity," J. W. Moule, 7 p.m.

Wed., Dec. 14th.—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Fuel Forum: A Discussion on Mutual Problems," 6.30 p.m.——E. MIDLANDS BRANCH: College of Technology, Leicester, "Noise in Ventilation Ducts," W. P. Jones, 6.45 p.m.——YORKSHIRE BRANCH: Griffin Hotel, Leeds, "Electrical Circuits and Switchgear for the Heating Engineer." B. Davies, 7.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Dec. 14th.—GENERAL MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Locomotives for Heavy Industry," K. J. Cook, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 9th.—GENERAL MEETING, APPLIED MECHANICS GROUP: 1, Birdcage Walk, Westminster, London, S.W.1, "Some Experiments on the Deflections and Vibrations of Drilling Machines," D. F. Galloway; "The Vibrations of Radial Drilling Machines Under Test and Working Conditions," S. A. Tobias and W. Fishwick, 5.30 p.m.

Mon., Dec. 12th.—DERBY A.D. CENTRE: Midland Hotel, Derby, "Some Experiences of Automobile Research," C. G. Williams, 7.15 p.m.——LUTON A.D. CENTRE: Assembly Hall, Town Hall, Luton, "The History of the Automobile Industry in Luton Over the Past Twenty-One Years," 7.30 p.m.——N.E. BRANCH: Neville Hall, Newcastle upon Tyne, "The Electrical Measurement of Steam Turbine Rotor Movements with Special Reference to the Operation and Design of Modern Power Plant," J. L. Ashworth, J. S. Hall and A. H. Gray, 6.15 p.m.

Tues., Dec. 13th.—AUTOMOBILE DIVISION GENERAL MEETING: 1, Birdcage Walk, London, S.W.1, "Some Notes on Carburation and Other Fuel System Problems," C. H. Fisher, 5.30 p.m.——S. WALES BRANCH: The Mackworth Hotel, Swansea, "The Roll-Setting Method of Automatic Control of Gauge, in Hot and Cold Rolling Mills," R. B. Sims and K. H. Slack, 6 p.m.——YORKSHIRE GRADUATES' SECTION: Chemistry Lecture Theatre, The University, Leeds, "The Production, Organisation and Inspection of a Fighting Vehicle," A. Glaisher, 7.30 p.m.

Wed., Dec. 14th.—GENERAL MEETING OF THE BRITISH NUCLEAR ENERGY CONFERENCE: Institution of Civil Engineers, Great George Street, London, S.W.1, "The Pressurised Water Reactor as a Source of Heat for Steam Power Plants," J. M. Kay and F. J. Hutchinson, 5.30 p.m.——N.E. BRANCH: Cleveland Institute, Middlesbrough, "The Development of Mechanical Draught Water Cooling Towers," L. Gilling Smith and G. W. Williamson, 6.15 p.m.——YORKSHIRE BRANCH: The University, Sheffield, "The Development and Scope of Work Study," G. Case, 6.30 p.m.

Thurs., Dec. 15th.—HYDRAULICS GROUP: 1, Birdcage Walk, London, S.W.1, Discussion on "Filtration of Liquids," 6.45 p.m.

Fri., Dec. 16th.—JAMES CLAYTON LECTURE: 1, Birdcage Walk, London, S.W.1, "Supply, Control and Combustion of Fuel to Aero-Gas-Turbines," E. A. Watson, 5.30 p.m.

INSTITUTION OF MINING AND METALLURGY

Thurs., Dec. 15th.—Geological Society, Burlington House, Piccadilly, London, W.1, "Panel Caving at the Creighton Mine of the International Nickel Company of Canada, Ltd.," A. F. Brock, R. J. McCormick and W. J. Taylor, "Equipping No. 3 Shaft, Harmony Gold Mining Company, Ltd.", S. C. Newman, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Dec. 9th.—EASTERN COUNTIES SECTION: Diocesan Hall, Tower Street, Ipswich, "Developments in the Manufacture and Packaging of Granular Compound Fertilisers," A. T. Brock, 7.30 p.m.——W. WALES SECTION: Central Library, Alexandra Road, Swansea, "Modern Production and its Influence on Costs," J. P. Wilson, 7.30 p.m.

Mon., Dec. 12th.—HALIFAX SECTION: George Hotel, Huddersfield, "New Methods of Measuring Productivity with Particular Reference to the Welding Industry," A. G. Thompson, 7.15 p.m.——SHEFFIELD SECTION: Grand Hotel, Sheffield, "Fabrication for Heavy Engineering," J. A. M. Stirling and R. Bagshaw, 6.30 p.m.

Tues., Dec. 13th.—DONCASTER SECTION: Danum Hotel, Doncaster, "Safety in Industry," J. L. Hobson, 7 p.m.——OXFORD SECTION: Town Hall, Oxford, "Technical Training for Automation," S. A. J. Parsons, 7.15 p.m.

Wed., Dec. 14th.—Technical College, Wulfruna Street, Wolverhampton, "The Implications of Automation," F. G. Woollard, 7 p.m.——PRESTON SECTION: College of Further Education Accrington, "Reading Technique," H. Bayley, 7.15 p.m.——DUNDEE SECTION: New Imperial Hotel, 15, Tally Street, Dundee, "New Methods of Measuring Productivity with Particular Reference to the Welding Industry," A. G. Thompson, 7.30 p.m.

Thurs., Dec. 15th.—GLASGOW BRANCH: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, "Radial Drilling Time-Saving Devices," Phillip Jackson, 7.30 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "Production Methods in Railway Workshops," T. B. Maddison, 7.15 p.m.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Tues. Dec. 13th.—Caxton Hall, Westminster, London, S.W.1, "The Biology of Rivers in Relation to Pollution," F. T. K. Pentelow, 6 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Thurs., Dec. 15th.—11, Upper Belgrave Street, London, S.W.1, "The Tignes Hydro-Electric Scheme," R. Giguet, 6 p.m.——WALES AND MONMOUTHSHIRE BRANCH: S. Wales Institute of Engineers, Cardiff, "Prestressed Concrete as Applied to Building Frames," F. Walby, 6.30 p.m.

IRON AND STEEL INSTITUTE

Wed., Dec. 14th.—IRON AND STEEL ENGINEERS' GROUP: 4, Grosvenor Gardens, London, S.W.1, "The Roller-Straightening of Sections and Rails," W. A. J. Dinwoodie, 10.30 a.m. to 12.45 p.m.; Buffet Luncheon, 12.45 p.m. to 2 p.m.; "Flying Shears for Bars and Billets: Mechanical Design Features," R. Stewartson, 2 p.m. to 4 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 9th.—INAUGURAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, Presidential Address, "Dams," G. M. Binnie, 7.30 p.m.

Mon., Dec. 12th.—N.W. SECTION: Engineers' Club, Albert Square, Manchester, "Factors Influencing the Choice of Lubricants," S. E. Holmes, 7.30 p.m.——SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "Motor Bus Maintenance," T. F. Bailey, 7.30 p.m.

Fri., Dec. 16th.—Pepys House, 14, Rochester Row, London, S.W.1, Gadget Evening, 7 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., Dec. 15th.—Mining and Technical College, Wigan, "Bold Colliery Modernisation," F. E. Rainford, 3.15 p.m.

NEWCOMEN SOCIETY

Wed., Dec. 14th.—GENERAL MEETING: Lecture Theatre, Science Museum, South Kensington, London, S.W.7, "The Waterwheels of John Smeaton," Paul N. Wilson, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Dec. 9th.—Mining Institute, Newcastle upon Tyne, "Ship Structural Weight Similarity," E. V. Telfer, 6.15 p.m.

OLD CENTRALIANS

Wed., Dec. 14th.—Mapleton Restaurant, 39, Coventry Street, London, W.1, "Netherlands Railways," F. Q. Den Hollander, 12.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Dec. 13th.—MIDLAND COUNTIES BRANCH: Birmingham and Midland Institute, Paradise Street, Birmingham, "The Place of Cement in Concrete Making," E. S. Shellard, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

Fri., Dec. 16th.—SECTION LECTURE: Library, 4, Hamilton Place London, W.1, "Airships of To-day," Lord Ventry, 7 p.m.

ROYAL SOCIETY OF ARTS

Wed., Dec. 14th.—John Adam Street, Adelphi, London, W.C.2, "Latin-American Architecture, Henry-Russell Hitchcock," 2.30 p.m.

SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS

Mon., Dec. 12th.—The University, St. George's Square, Sheffield, Annual General Meeting, Lecture on "The Applications of Hard Metal Tools," 7.30 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Wed., Dec. 14th.—Burlington House, Piccadilly, London, W.1, "Chromate Pigments for Metal Protection," H. G. Cole, 6.30 p.m.

SOCIETY OF ENGINEERS

Mon., Dec. 12th.—17, Victoria Street, London, S.W.1, Annual General Meeting, 5.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Dec. 16th.—Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Some Aspects of Blast-Furnace Operation," E. H. Baldwin, 6.45 p.m.